Zero Energy Buildings

The impact of different definitions on achieving the ZEB goals. Comparative analysis of five buildings.

Vasiliki (Vanta) Kyriakou, Architect engineer

SID: 3302100021

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A thesis submitted for the degree of

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ABSTRACT

The aim of this dissertation will be the investigation of the impact of different definitions of Zero Energy Buildings, on achieving the ZEB goals.

The contribution of this study is to examine five public buildings in Kalamaria, which are all two storey buildings, built before 1955. For each an energy performance audit will be done and results will be the output of the TEE-KENAK software. Discussion on the results and assessment will draw conclusions.

Depending on the bibliography and lessons learned from other case studies all over the world, this study concentrates to the Greek special conditions and sets the specifications of reaching the ZEB goals in the context of national limitations. When specifying to old buildings stock, more limitations are set, which are also taken under consideration.

Understanding the energy performance of the current stock of buildings is an important step toward reaching the ZEB goal.

The buildings included in this study are:

1. *The municipality central offices building (restored)*
2. *The cultural organization building (restored)*
3. *A primary education school building*
4. *A social services, disabled school and library building*
5. *A social services offices and nursery building*

Vasiliki (Vanta) Kyriakou

Date: 29 / 10 / 2012

PREFACE

Reducing energy consumption and eliminating wastage are among the main goals of the European Union (EU). EU support for improving energy efficiency will prove decisive for competitiveness, security of supply and for meeting the commitments on climate change made under the Kyoto protocol. There is significant potential for reducing consumption with cost-effective measures. With 40% of our energy consumed in buildings, the EU has introduced legislation to ensure that they consume less energy.

A key part of this legislation is the **Energy Performance of Buildings Directive (Directive 2002/91/EC, EPBD)**, first published in 2002, which required all EU countries to enhance their building regulations and to introduce energy certification schemes for buildings. All countries were also required to have inspections of boilers and air-conditioners.
The introduction of national laws meeting EU requirements was very challenging, as the legislation had many advanced aspects. It was a great opportunity to mobilize energy efficiency in EU buildings, but also a formidable and continuing challenge for many EU countries to transpose and implement the Directive.

To support EU countries in this task, **the Concerted Action (CA) EPBD** was launched by the European Commission to promote dialogue and exchange of best practice between them. The key aim was to enhance the sharing of information and experiences from national adoption and implementation of this important European legislation. An intensely active forum of national authorities from 29 countries, it focused on finding common approaches to the most effective implementation of this EU legislation.

The original Concerted Action EPBD came to a close in June 2007, but, with an implementation deadline of 2009 for Certification and Inspections, a second phase running until 2010 was launched immediately after the end of the first Concerted Action. When initiated in 2005, most countries were still at the planning stage. After stimulating advancement and convergence across the EU, the approach was enhanced in 2007.

The Greek Law 3661 – "Measures for the reduction of the energy use in buildings", Official Gazette 89/19th of May 2008 incorporated the provisions of the Directive 2002/91 of the European Parliament and Council. The issue of an Energy Performance Regulation is foreseen and five (5) thematic categories are distinguished:

1. Definition of minimum energy demands for energy performance
2. Calculation method for the energy performance of new-built and existing constructions
3. Issue of energy efficiency certificate
4. Boilers and air-conditioning systems audit
5. Provision for specialized and certified energy auditors

With the adoption of **the recast EPBD**, **Directive 2010/31/EU of the European Parliament and Council** of 19 May 2010, EU Member States faced new tough challenges.**)** Foremost among them, **moving towards new and retrofitted nearly-zero energy buildings by 2020 (2018 in the case of Public buildings),** and the application of a cost optimal methodology for setting minimum requirements for both the envelope and the technical systems, the current Concerted Action thus aims at transposition and implementation of the EPBD recast, and it runs from 2011 until 2015. The first part (until 2012) focuses on transposition of the recast EPBD, the second part of the Concerted Action shall focus on implementation and lessons learned.

The Directive 2010/31 on the energy performance of buildings (recast), issued the following:

- Buildings shall be nearly zero energy balance buildings after 2018
- Public buildings have to, for residential buildings it is not binding.
- EU member states are to set specific, binding targets for nearly zero energy balance buildings in 2015 and 2020.
- Less exceptions (p.e. vacation houses).
- Additional funding on an EU and on a national level.
- Reduction or exemption of VAT in energy saving building elements and systems.
- Compulsory smart metering installation.

The Greek Law 3855 FEK 95/23-6-2010 – "Measures for the upgrade of the energy performance of buildings at the final use, energy services and other issues"; Official Gazette 95/23rd of June 2010, incorporated the provisions of the Directive 2010/31 of the European Parliament and Council.

The Greek Legislation in the sector of energy is:

- The Electricity Laws (3426/2005, 4001/2011)
- The Natural Gas Laws (3428/2005, 4001/2011)
- The RES Laws (3468/2006, 3734/2009, 3851/2010, 4001/2011)

Latest news from the ASHRAE's eNewsletter, inform that "**EU Adopts Energy Efficiency Plan**".
"The European Parliament voted in favor of **new energy-efficiency legislation** designed to help the European Union's member nations to reduce energy consumption by 17% by 2020. It is projected that the move could save the EU up to $75 billion annually through reduced fuel imports, and meet greenhouse gas reduction targets. The policies require the EU nations pass new energy-efficiency legislation that will require all large businesses to undertake energy-use audits every four years. In addition, the directive aims to **push advanced energy efficiency targets for public sector buildings**. The various governments have 18 months to transpose the new legislation into national law".
(The HVAC&R Industry, ASHRAE's eNewsletter. October 25, 2012: Vol. 11, No. 43)

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to my son, Thomas,

for the time stolen from him, to complete these master studies

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Start with the one that already exists.

"The Greenest Building: Quantifying the Value of Building Reuse"

1. INTRODUCTION

Defining the problem

A zero energy building can be defined in several ways. Four commonly used definitions are: zero site energy, zero source (primary) energy, zero energy costs and zero energy emissions.
The way the zero energy goal is defined, affects the choices designers make to achieve this goal and whether they can claim success. The ZEB definition can emphasize different strategies.

Despite the excitement over the phrase "zero energy" we lack a common definition, or even a common understanding, of what it means.
In general, a net zero-energy building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies.

The ZEB definition can emphasize demand-side or supply strategies and whether fuel switching and conversion accounting are appropriate to meet a ZEB goal. Four well-documented definitions—net-zero site energy, net-zero source energy, net-zero energy costs, and net-zero energy emissions—are studied; pluses and minuses of each are discussed.
At the heart of the ZEB concept is the idea that buildings can meet all their energy requirements from low-cost, locally available, nonpolluting, renewable sources. At the strictest level, a ZEB generates enough renewable energy on site to equal or exceed its annual energy use. (Torcellini, Pless, and Deru, 2006)

What is a Nearly Zero Energy Building?
A "nearly zero energy building" is a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.
(Article 2 (2) of Directive 2010/31/EU on the recast of the EPBD)

What is the Target
(a) by 31 December 2020, all new buildings are nearly zero-energy buildings; and
(b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero energy buildings.
(From Article 9 of the EPBD recast)

Selected National Targets for New Buildings

Denmark: 75% by 2020 (c.f. base year 2006)
Finland: Passive house standards by 2015
France: By 2020 new buildings are energy-positive
Germany: By 2020 buildings should be operating without fossil fuel
Hungary: Zero emissions by 2020
Ireland: Net zero energy buildings by 2013
Netherlands: Energy-neutral by 2020 (proposed)
Norway: Passive house standards by 2017
UK (England &Wales): Zero carbon as of 2016

Is Zero Energy Achievable?

Under the EC's Impact Assessment, several options were assessed, including *Option D4: Setting up EU–wide low or zero energy/carbon buildings/passive house requirements.* Compared to the other options for improving the energy performance of buildings assessed by the Commission, this option gave by far the largest energy and carbon savings and resulted in the largest number of jobs created (240,000-580,000). It also had a low administrative burden.

The Commission felt that such a requirement would pose a significant challenge to the construction industry to build such homes and would increase prices by 7% to 15%.

. . . Therefore, a softer approach was recommended, which was to include an obligation for the development of 'roadmaps,' wherein Member States would show their commitment toward achieving low energy/emission houses in the future and the concrete measures they plan to undertake.

Article 9 states that Member States shall draw up national plans for increasing the number of nearly zero-energy buildings. These national plans may include targets differentiated according to the category of building.

Article 9 further states: "The Commission shall evaluate the national plans referred to in paragraph, notably the adequacy of the measures envisaged by the Member State in relation to the objectives of this Directive. . . "The Commission shall by 31 December 2012 and every three years thereafter publish a report on the progress of Member States in increasing the number of nearly zero energy buildings. On the basis of that report the Commission shall develop an action plan and, if necessary, propose measures to increase the number of those buildings and encourage best practices as regards the cost-effective transformation of existing buildings into nearly zero-energy buildings."

The EPBD obliges MS to: "assure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels". MS shall also: "take the necessary measure to ensure that minimum energy performance requirements are set for building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are replaced or retrofitted, with a view to achieving cost-optimal levels" (EPBD art. 4.1; preamble 14).

Cost-optimal level is defined as: "the energy performance level which leads to the lowest cost during the estimated economic lifecycle". MS will determine this level taking into account a range of costs like investments, maintenance, operating costs, energy savings. The economic lifecycle is determined by each Member State. It refers to the estimated economic lifecycle of a building or building element. Cost-optimal lies within the cost efficiency range (EPBD art. 2.14).

….The Commission is charged with producing a Comparative Methodology Framework and accompanying guidelines. In effect, MS are required to show, every five years, that their building energy requirements are reasonably close to levels that can be shown to be cost-optimal in their particular national circumstances.

The EPBD obliges MS to report on the comparison between the minimum energy performance requirements and calculated cost-optimal levels using the Comparative Methodology Framework provided by the Commission (EPBD Art 5.2, 5.3, 5.4 and Annex III). The report should also provide all input data and assumptions made.

The Commission will also provide information on estimated long-term energy price developments.

The recast EPBD does *not* demand that MS set their minimum performance requirements at levels that are cost-optimal. **It *does* require them to report how their requirements differ from cost-optimal levels** (implicitly as far as underperformance is concerned). If there are "significant" differences – exceeding 15 % (presumably meaning that they allow energy consumptions that are 15 % higher than would be cost-optimal) - MS should justify them or plan steps to reduce the difference. Clearly this first requires the calculation of a cost-optimal requirement.

Cost-effectiveness and cost-optimality can be considered from several different perspectives, each of which will usually provide a different result. We summarize three important perspectives:
- of society as a whole: the "macro" economic perspective
- of individual end-users
- of idealized end-users: the "micro" economic perspective

Each of these serves a different purpose and MS will, no doubt, assign a different importance to each of them when setting requirements.

Energy saving measures
Putting together a list of energy saving measures is relatively simple. In the case of new buildings packages of measures will be taken into account to establish cost optimal levels. In identifying the packages it is important to apply the so-called Trias Energetica. **In case of the existing buildings stock the energy saving of the measure depends on the energy characteristics of the building as it is.** Both packages and single measures can be applied to existing buildings undergoing a major renovation. In case of maintenance or renovation the cost for energy measures should be defined as additional cost. These costs are sometimes hard to determine. Preferably the Trias Energetica should also apply for the existing building stock. In practice with maintenance driven interventions in a building this is not always possible. The diversity and practical restrictions that occur in the existing stock complicate the energy efficiency analyses and causes a lot of uncertainties. Nevertheless, improving the existing building stock is crucial for the realization of the climate targets.

Analyzing the cost efficiency of measures in the existing building stock is common practice in consultancy for specific buildings. For the purpose of setting or comparing energy performance requirements, measures have to be judged in a more general and transparent way in order to be valid for enforcing requirements. There is hardly any experience how to do this properly. It is therefore of great importance to organize knowledge exchange and to share experiences. The framework should take into account the fact that adjustments and refinement shall be needed in the near future.

Old buildings have a specific interest, because when they are restored and reused considerable changes take place, concerning their performance.

- The building envelope is chanced due to interventions aiming to stabilize the supportive structure elements.
- The use is chanced (hours per day, months per year).

Why is it important

Construction is one of the most important economic sectors worldwide. The total world's annual output of construction is close to $3 trillion and constitutes almost one-tenth of the global economy. About 30% of the business is in Europe, 22% in the United States, 21% in Japan, 23% in developing countries and 4% in the rest of the developed countries. Buildings use almost 40% of the world's energy, 16% of the fresh water and 25% of the forest timber, while is responsible for almost 70% of emitted sulphur oxides and 50% of the CO2.

Construction represents more than the 50% of the national capital investment. It employs more than 111 million of employees and it accounts for almost the 7% of the total employment, and 28% of the global industrial employment.
Given that every job in the construction sector generates 2 new jobs in the global economy, it can be said that the construction sector is in a direct or indirect way is linked to almost 20% of the global employment.

Reusing and retrofitting existing buildings with an average level of energy performance almost always offers environmental savings over demolition and more energy-efficient new construction.

Savings from reuse are between 4 and 46 percent over new construction when comparing buildings with the same energy performance level. The reuse-based impact reductions may appear small when considering a single building, however the "absolute carbon-related" impact reductions can be substantial when these results are scaled across the building stock of a country.

In Greece the building stock is shown at the following table.

Year of construction	Buildings stock
Greece (in total)	3.990.970
Before 1945	606.143
1946-1980	2.164.072
1981-2000	1.220.755
Urban regions	1.950.060
Before 1945	180.871
1946-1980	1.093.242
1981-2000	675.947

As we can see, about 70% of the building stock in Greece is built before 1980, which means that extended energy saving measures is needed, in order to fulfil the minimum performance requirements.

Understanding the energy performance of the current stock of buildings is an important step toward reaching the ZEB goal.

Questions to be answered

The following questions should be answered:

What exactly is a Zero Energy Building?

What do we mean by the terms:
"site", "source or primary", "CO_2 emissions" and "cost" ZEB?

What are the implications of using different definitions?

More specifically, concerning the existing building stock:

Is there a possibility for existing buildings to become Zero Energy Buildings (ZEB)?

Or just use another specification: the Zero Energy Capable Buildings (ZEC)?

The answer is: DEPENDS,
on what we mean by zero-energy building, on the definition.

So, we should explore the definitions.

Contribution of the present research

Five public buildings from the existing building stock are going to be examined and their energy performance will be analyzed. All of them are built before 1955 and all are renovated to some extent. All except one are of the same building type: orthogonal plan, two-storey, flat roof, no basement, about one meter over the level of the ground. Only the cultural organization building has a rectangular plan, basement and roof.

Their performance differentiate by the fact that one of them (the municipal building) was totally reconstructed in 1995, reinforcing the structure and insulating the external envelope, changing as a result the whole performance of the building. The heating and cooling system was changed to **air ducts.**

The others were renovated only by changing the windows to aluminum double glazing. The heating system was upgraded from oil to natural gas in three of them. Two of the buildings remained with the old oil fired burner.

As far as their function is concerned, two are office buildings (A and B), one is a school building (C) and the other two (D and E) have mixed use different for each level (library, disabled school, offices and a nursery).

The structure of the dissertation

In the Chapter 1 – Introduction a picture of the whole dissertation is presented:
a brief definition of the problem, the importance of the subject studied, questions which should be answered and the contribution of the present research in relation to other similar studies.

Chapter 2 – Literature Review contains the related work published on the topic by accredited scholars and researchers. The most significant and the most relevant to the subject of ZEB were selected and presented, mentioning their strong/weak points. Finally it is explained where this work fits in.

The problem is specially analyzed in Chapter 3 – Definition of the Problem. Depending on the bibliography and lessons learned from other case studies all over the world, this *study concentrates to the Greek special conditions and sets the specifications of reaching the ZEB goals in the context of national limitations. When specifying to old buildings stock, more limitations are set, which are also taken under consideration.*

Chapter 4 – Contribution, includes the contribution of this study, achieved by the following steps:

1. *Identify the methodology*
2. *Select the buildings (criteria)*
3. *Present the general characteristics of the selected buildings*
4. *Energy audit for each building – Input data to TEE-KENAK software*
5. *Results of the energy audit – Output*
6. *Analysis and discussion of the results*
7. *Evaluation and assessment*

In Chapter 5 – Conclusions, the results of the assessment made in the previous chapter are presented as general conclusions, which could be used to other similar cases.

Chapter 6 includes the bibliography used for this research.

2. LITERATURE REVIEW

The difference between site and source energy is a vital concept to understand when looking at the energy performance of buildings.

K. Ueno and J. Straube in **"Understanding Primary/Source and Site Energy"** discussed the subject: **"**A building's energy consumption can be measured in terms of its fuel use: gallons of fuel oil, kWh of electricity, or therms of gas. Although all of them are in different units, we can ultimately measure them in terms of units of energy—e.g., "How much water can you boil with this energy?" For our purposes, energy is commonly measured in Btus (U.S. units) or kWh (metric units); for reference, the definition of a Btu, or British thermal unit, is the energy it takes to heat one pound of water by one degree Fahrenheit. Note that kWh, although it is typically used for electricity, is a unit of energy (not just electricity)—and can be applied to any fuel source. (Ueno, K., Straube J., 2010)

If you add up all the energy (Btus) you are consuming at the meter, this is what is known as "site" energy. However, this is not the full picture. The problem is that the process of generating electricity incurs substantial losses—enough that for every unit of electricity at the plug, it might have been necessary to "burn" about 3 times that amount of energy (coal, gas, nuclear, etc.) at the power plant"—see Figure 1.

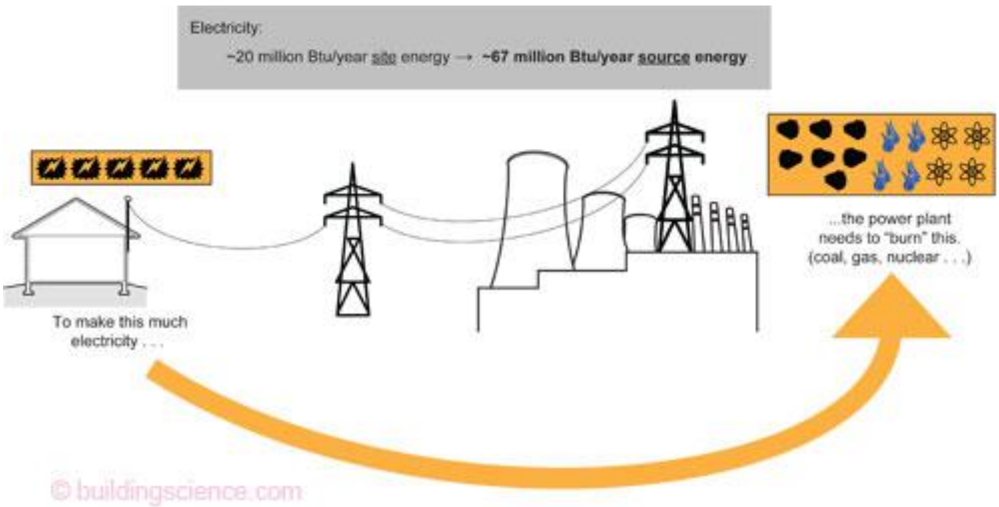


Figure 1: *Source energy from power plant to electric service entrance.*
[Ueno, K., Straube J., 2010, http://www.buildingscience.com]

If you account for the energy consumed at the power plant, this is known as “source energy” or “primary energy.” The EPA’s definition is:

Source energy is a measure that accounts for the energy consumed on site in addition to the energy consumed during generation and transmission in supplying the energy to the site.

“Source energy is much more important than site energy”, Ueno and Straube state, “if the concern is environmental performance. Site energy is useful because it can be unambiguously measured”. (Ueno, K., Straube J., 2010)

Numerous building programs, like Building America, EPA Energy Star, Architecture 2030, the German Passiv Haus, and the Greek **TEE-KENAK** all use source energy metrics.

Some of the current US national average figures are:

- Site-to-source electricity: 3.365
- Site-to-source natural gas: 1.092
- Site-to-source fuel oil: 1.158
- Site-to-source propane: 1.151

Ueno and Straube finally say that: “When people talk about electricity being “clean power”, this typically fails to acknowledge the reality of source energy. All that’s happened is that <u>the pollution has been moved from your chimney to somewhere that you can’t see it</u> **-** it hasn’t magically disappeared. In fact, with the current power mix, it is reasonable to argue that <u>electricity is dirtiest fuel</u>. This does not mean electricity should not be used, only that it should be used wisely”.

A report by M. Deru and P. Torcellini, **“Source Energy and Emission Factors for Energy Use in Buildings”,** provides the energy and emission factors to calculate the source energy and emissions for electricity and fuels delivered to a facility and combustion of fuels at a facility. The factors for electricity are broken down by fuel type and presented for the continental United States, three grid interconnections, and each state. The electricity fuel and emission factors are adjusted for the electricity and the useful thermal output generated by combined heat and power (CHP) plants larger than one megawatt. The energy and emissions from extracting, processing, and transporting the fuels, also known as the precombustion effects, are included. (Deru, M. and Torcellini, P., 2007)

What about using energy costs instead?

Some (notably ASHRAE 90.1 and LEED) have considered using the cost of energy as a metric, instead of bothering with site-source conversions, Btus, kWh, etc. First, costs are commonly used in economic analyses, and are what many building owners care about the most. Second, energy costs are actually a rough surrogate for/approximation of source energy. This is part of the reason why ASHRAE Standard 90.1 (the energy efficiency standard for large buildings), uses cost in its “building energy cost method” (which calculates the effectiveness of various energy conservation measures) (Jarnagin, 2010).

Ueno and Straube are concluding the fact that energy costs can vary greatly by geographic region, season, and even time of day. Energy costs are also somewhat meaningless across time and space.

“So if someone is trying to compare buildings A and B, energy cost can easily give you a distorted picture—or one that is only accurate for the next week or two. It is better to take the energy units, and then figure out the energy costs as necessary. This allows estimation (for instance) what would happen if energy costs change over time”.

“A high performance building in Europe”, the authors say, “may have the same energy cost as a mediocre building in Arizona, but use less than half as much energy and emit a third as much pollution. Reporting the source energy consumption would allow a comparison of buildings on different continents and at different times”. (Ueno, K., Straube J., 2010)

A first status report on Zero Energy Commercial Buildings, New Buildings Institute (NBI) gathered information to determine characteristics, costs and features of Zero Energy Buildings (ZEBs) recently constructed in the U.S.A. A research report, March 2012, **“Getting to Zero 2012 Status Update: A First Look at the Costs and Features of Zero Energy Commercial Buildings”**, defined ZEBs as buildings that use no more energy over the course of the year than they produce from on-site renewable sources.

In brief, NBI found that:

• ZEBs have been successfully built in most climate zones of the United States.

• The majority of ZEBs to date are small or very small buildings.

• All buildings to date use photovoltaic (PV) panels to provide their on-site renewable energy.

• Many of the earliest examples are academic buildings or environmental centers, in effect, demonstration buildings sometimes with low occupancy levels. More recent buildings include office buildings, K-8 schools and a credit union; buildings that represent large numbers of “average” or typical buildings. This trend is continuing, and ZEBs are becoming larger and more complex.

• ZEBs are constructed using readily available technology. An integrated design approach with careful attention to building siting and layout, envelope, mechanical systems, and electrical systems is critical to achieve the high levels of energy efficiency employed. Unique or experimental systems are infrequently used to reach net zero goals, but the emergence of new technologies will be a factor in the expansion to more building types.

• As the larger office buildings market moves towards ZEB, minimizing plug loads and other miscellaneous or “unregulated” loads is a priority.

• Reported incremental costs are only available from a few ZEBs, and conclusions or trends are difficult to derive from the limited information available. However, the few reported ZEBs appear to show lower overall incremental costs than the modeled estimates, possibly due to trade-offs with other features in the design and construction process. These costs range from 0% to 10%.

NBI reviewed data from a variety of additional low-energy buildings that we have studied for other purposes, and called these buildings Zero Energy-Capable (ZEC). These buildings demonstrated energy efficiency levels in the range of the documented ZEBs, but many did not include any (or sufficient) on-site renewable generation to cover their annual energy use.
The 2003 national average energy use intensity (EUI) of all U.S. commercial buildings is 93 kBtu/square foot (sf). The least efficient buildings in this study had a EUI of 35 kBtu/sf, while the most efficient used less than 10% of the national average.

This paper focused on cases in which the zero energy goals are achieved on a single site. While location, space constraints, and building activity type won’t always accommodate this goal, the single site lessons also inform the pathway to achieving zero energy goals on a district or regional basis.

NBI included a review of several modeling studies of ZEBs and ZE-Capable buildings. These studies showed incremental costs for common building types ranging from as low as 3% to a high of 18%, depending on building type, location cost factors, and climate (i.e. energy efficiency strategies needed in a given climate zone to achieve ZE-Capable levels of performance), not including an appropriately sized PV system.

The most cost-effective path to zero energy is to focus first on these efficiencies, reducing the amount of energy that must be produced from PV purchase and installation.

Deep energy savings require an integrated design approach considering interactive effects of multiple physical, mechanical, and behavioral measures. It is often hard to isolate the incremental cost of individual measures. (NBI report, 2012)

The authors Torcellini, Pless and Deru, 2006, have developed a ranking of renewable energy sources in the ZEB context.
The following table shows this ranking in order of preferred application. The principles they have applied to develop this ranking are based on technologies that:

• Minimize overall environmental impact by encouraging energy-efficient building designs and reducing transportation and conversion losses.

• Will be available over the lifetime of the building.

• Are widely available and have high replication potential for future ZEBs.

Table 1. ZEB Renewable Energy Supply Option Hierarchy (Torcellini, Pless, and Deru, 2006)

Options	ZEB Supply-Side Options	Examples
0	Reduce site energy use through low-energy building technologies	Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.
	On-Site Supply Options	
1	Use renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building.
2	Use renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building.
	Off-Site Supply Options	
3	Use renewable energy sources available off site to generate energy on site	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat.
4	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other "green" purchasing options. Hydroelectric is sometimes considered.

Renewable energy resources from outside the boundary of the building site could arguably also be used to achieve a ZEB. (Torcellini, Pless, and Deru, 2006)

This approach may achieve a building with net zero energy consumption, but it is not the same as one that generates the energy on site and should be classified as such.

The authors use the term **"off-site ZEB"** for buildings that use renewable energy from sources outside the boundaries of the building site.

Efficiency measures or energy conversion devices such as daylighting or combined heat and power devices cannot be considered on-site production in the ZEB context. Fuel cells and microturbines do not generate energy; rather they typically transform purchased fossil fuels into heat and electricity. Passive solar heating and daylighting are demand-side technologies and are considered efficiency measures.

Energy efficiency is usually available for the life of the building; however, efficiency measures must have good persistence and should be "checked" to make sure they continue to save energy**. It is almost always easier to save energy than to produce energy.** (Torcellini, Pless and Deru, 2006)

The above authors studied six buildings. There were many lessons learned in the design, construction, and operation of these buildings. Each building's performance was less than expected. This was due to a number of factors. First, design teams were optimistic about the behavior of the occupants and their acceptance of systems. Occupant loads (mostly plug loads) are often much higher than anticipated during the design process. There is always occupancy before or after the scheduled time. Building systems do not operate ideally and typically, simulations predict ideal operating conditions; therefore, the buildings consume more energy or generate less energy than expected. Building space temperatures are not set back as much as anticipated for the lengths of time that were expected. Insulation values are often inflated when designing the building. In the case of the TTF, the thermally broken window frames were not installed. In all cases, thermography indicated thermal leaks in the building, especially at corners and where

the building hits the ground—a very difficult area to insulate. These results are similar to those found by other researchers. (Branco 2004; Norford 1994)
Monitoring systems should be separate from the energy management systems. It takes an increased effort to maintain proper operation of detailed monitoring systems.

Integrating new technologies can be challenging. In all buildings, daylight sensors did not function properly with the lights and had to be either changed or reprogrammed.
One issue across all the buildings was the ability to consistently define metrics for the buildings. Even with the same staff evaluating each building, determining consistency for measuring energy consumption proved difficult. Methods had to be established to define base-cases, energy consumption, and conditioned area calculations. This has become the framework for a new set of performance metrics being developed.
What to include in the energy measurements was also an issue.
In all cases, -even covering the roof with photovoltaic panels- none of the buildings can be net energy exporters within their own footprint (Hayter 2002). The buildings all have more loads than is available with current PV technology.
Creating energy cost goals during design, and verifying the costs are difficult due to the instability in energy prices.
Getting long-term weather data for the exact building site can be a problem. Microclimates can significantly change results.
Some projects did not complete simulation throughout the design process.
Caution must be exercised in comparing the initial predictions, analysis, and actual data (these numbers can vary greatly). Measurable goals must be defined.

Conclusions of the above study were the following:
Although all of the buildings have better than typical energy performance, none of them perform as well as predicted. The lower performance is mainly due to higher than expected occupant loads and systems not performing together in an ideal fashion. In some cases, the initial automated control algorithms reflected a flawed understanding of how the innovative systems in these buildings should function together. Commissioning did not always catch these problems because it primarily checks for proper individual system operation, but it does not address the optimal performance of the whole building once it is in operation. All of the buildings benefited from post occupancy fine-tuning of system operations, resulting from building performance monitoring. Achieving and maintaining high performance of the building requires a constant effort, which is absent in most buildings. Continually tracking building performance is expensive and requires motivated, trained staff. However, advances in metering technology, computerized communications, and automated controls offers hope for the future. Additional research work to reduce costs, better optimize control strategies, and improve reliability is needed to realize the full energy savings potential of high-performance buildings. In addition, whole-building energy simulation programs must be continually enhanced to keep pace with advances in new building energy technologies.

A report produced by the Preservation Green Lab of the National Trust for Historic Preservation **"The Greenest Building: Quantifying the Value of Building Reuse"** provides the most comprehensive analysis to date of the potential environmental benefit of building reuse.

This study **concludes that**, when comparing buildings of equivalent size and function, building reuse almost always offers environmental savings over demolition and new construction.
These findings add to the already impressive economic and quality of life advantages offered by building reuse.

Resolving many conflicted arguments, this study confirms that reusing and retrofitting existing buildings with an average level of energy performance almost always offers environmental savings over demolition and more energy-efficient new construction. The research provides the most comprehensive analysis to date of the potential environmental impact reductions associated with building reuse. The Preservation Green Lab utilizes Life Cycle Analysis (LCA) methodology to compare reuse and renovations with new construction over the course of a 75-year life span.

The study examines four environmental impact categories that include climate change, human health, ecosystem quality and resource depletion amongst these six building typologies: single-family home, multifamily building, commercial office, urban village mixed-use building, elementary school, and warehouse conversion. The typologies used are found in Portland, Phoenix, Chicago and Atlanta – the four U.S. cities selected to represent a different climate zone.

Patrice Frey, director of sustainability for the National Trust for Historic Preservation, says some of the most startling numbers came in the category of human health. Across all four cities, in almost all categories, the negative environmental impact of retro green for human health was between 12 and 38 percent less than for new construction. "It is more clear than ever that there are human health reasons to reuse rather than rebuild" Frey says.

Key findings of the study reveal "savings from reuse are between 4 and 46 percent over new construction when comparing buildings with the same energy performance level". The reuse-based impact reductions may appear small when considering a single building, however the "absolute carbon-related impact reductions can be substantial when these results are scaled across the building stock of a city."

Building Type	Chicago	Portland
Urban Village Mixed Use	42 years	80 years
Single-Family Residential	38 years	50 years
Commercial Office	25 years	42 years
Warehouse-to-Office Conv	12 years	19 years
Multifamily Residential	16 years	20 years
Elementary School	10 years	16 years
Warehouse-to-Residential Conversion*	Never	Never

Table This table illustrates the numbers of years required for new, energy efficient new buildings to overcome through efficient operations, the negative climate change impacts related to the construction process.
[Report produced by the "Preservation Green Lab" of the National Trust for Historic Preservation, 2012]

The impact of green retro versus green new can be seen in the stats from the U.S. Green Building Council, which shows that LEED certification for existing buildings (LEED EB) **start to outpace** LEED for new construction (LEED NC) in 2011. That trend has continued in 2012, with LEED EB logging in 25.3 million more square feet than LEED NC. (Report produced by the "Preservation Green Lab" of the National Trust for Historic Preservation, 2012)

Although warehouse conversions and school additions require more material inputs than other types of renovation projects, reusing these buildings is still more environmentally responsible – in terms of climate change and resource impacts – than building anew, particularly when these buildings are retrofitted to perform at advanced efficiency levels. Better tools are needed to aid designers in selecting materials with the least environmental impacts. Such resources would benefit new construction and renovation projects alike.

Elementary schools

	Rehabilitation and Retrofit	
Building Name		
Location		
Year Built		
Year Renovated		
Building Height		
Space Summary		
Square Meters		
Building Program Elements	Classrooms, gymnasium, cafeteria and kitchen, auditorium, commons, music room	
Renovation Description	Interior finishes updated, repairs to mechanical system, operable windows refurbished	refurbishment of existing rooms, energy upgrades
Core & Shell		
Structure Type	Concrete and Brick	
Envelope	Double hung operable windows, single glazing, masonry wall system	Masonry wall system, rigid and batt insulation,upgraded windows, SBS roofing
Cladding	Terra cotta	Masonry
% Glazing (window : walll)		
HVAC System		Four pipe system, gas boiler and chiller
Interior		
Type	Closed office	
Scope	Carpet, vinyl flooring, metal framing, casework Carpet, plaster/GWB, metal, masonry, casework, terrazzo lobbies /corridor	VCT floor, ACT, metal framing, drywall
Climate Zone Relative EUI (kbtu/sf/yr) **End-Use** Space Cooling Space Heating DHW Vent Fans Pumps & Aux Extr. Lighting Misc. Equipment Int. Lighting		

This study reveals that the quantity and types of materials used in a reuse scenario can reduce or even eliminate the environmental advantage associated with reuse. For example, the converted warehouses and school addition require larger material inputs relative to other reuse scenarios, and as can be seen in Figures 11-14, the benefits of reuse tend to be less than those seen in other buildings typologies.

Key findings of the study reveal impacts of Energy Performance Upgrades. An analysis of energy performance upgrades demonstrates the potential impacts associated with materials usage. Upgrades result in lower energy consumption over the lifetime of a building, and therefore yield a significant reduction in environmental impacts in those categories that are dominated by operating energy: Climate Change, Resource Depletion, and Human Health impacts. In the area of Ecosystem Quality, however, materials contribute more substantially to total environmental impacts.

J. Straube in **"The Function of Form: Building Shape and Energy",** says that "Building form and orientation do not have as large an impact on energy consumption as sometimes thought, especially for mid-size or large buildings. In all buildings, the ratio of enclosure area to floor area is important and hence simple shapes are preferred (as well as being less expensive to build and maintain)". (Straube, 2012)

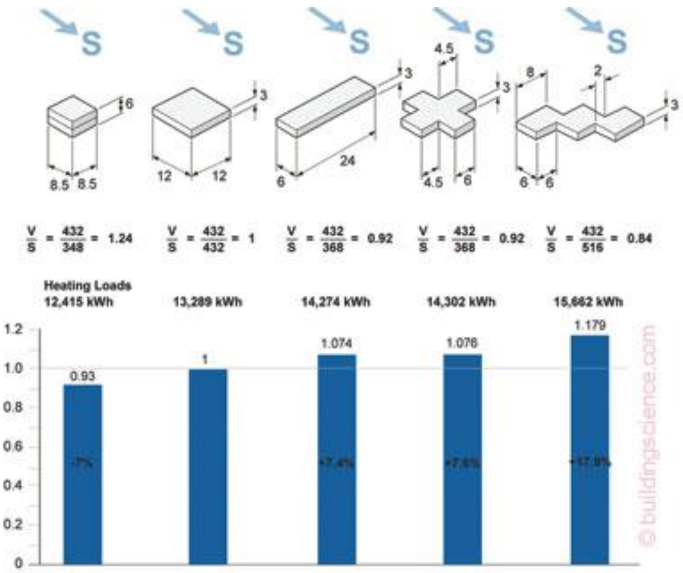


Figure 1: Impact of building shape on annual heating energy for a small 144 m^2 building in a cold climate. (Gratia & De Herde, 2003)

In Europe, the ratio of volume, V, to surface area, S, is a typical metric, labelled Compactness C:

Compactness C = Volume / Surface Area

The German energy code goes as far as prescribing higher R-values for buildings that are less compact than others.

The heating load of small buildings (e.g., houses) can vary by around 25% (Gratia and De Herde 2003) from the most compact (high C) to the most sprawling (low C) designs (Figure 1). Most ultra-low energy single-family houses have V/S ratios of around 1.0 or larger.

Another metric, preferred by this author for commercial buildings, is the ratio of the usable floor area, F, to above-grade enclosure area E. The more compact the form, the higher the ratio F/E. By explicitly removing volume from the assessment, this metric rewards buildings that require less floor-to-floor height.

Figure 2 depicts the impact of size and form on the floor: enclosure (F/E) area ratio for an office with a 14,000 ft^2 floor plate. As can be seen, the more compact the form (square is close to the perfect optimum, the circle), the higher the ratio.

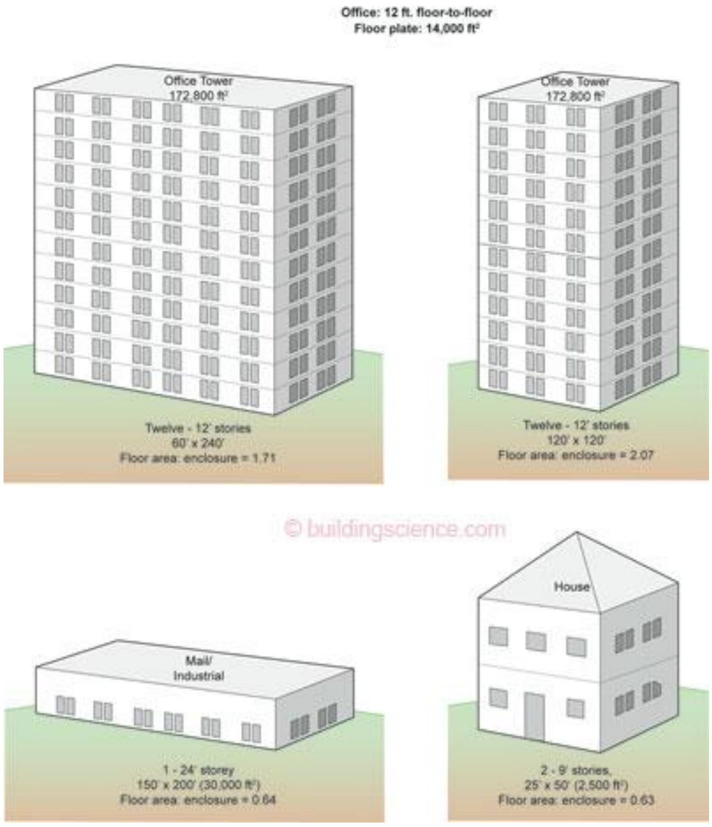


Figure 2: Impact of form on floor-to-enclosure (F/E) area ratio of different building types.

Figure 3 provides a range of F/E ratios for two sizes of office floor plan area (900 m^2 per floor). For the small office of 1800 m^2 a narrow two-storey form, ideal for natural ventilation and daylighting, has an F/E of 0.88, whereas a deep square plan has an F/E of 1.02. For the long narrow building to have the same enclosure heat loss coefficient, its overall average enclosure R-value would need to be 1.02/0.88 = 16% higher. In practice, this might be achieved by increasing the average R-value from 7.5 to 9.0. (Straube, 2012)

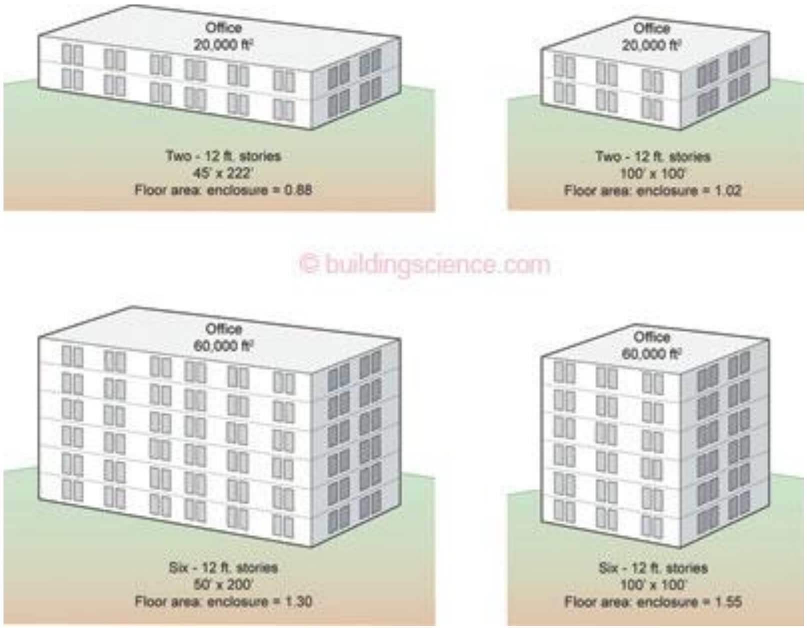


Figure 3: Floor area-to-enclosure area ratios for different building forms, each with 930 m^2 floor plate.

Research suggests that around 10% separates the energy use of a compact square building to a long, narrow "bar" building (Ross 2009). Such buildings with a simple, compact form with the short dimension of around 14 to 18 m. can reduce lighting loads (which occur mostly during the daytime occupancy) to a minimum using daylight controls and daylight harvesting. The small increase in heat loss that a non-square floor plate form incurs can be eliminated by increasing the enclosure performance at little cost. If at all possible, the building should be oriented towards the south (for useful winter solar gain while easily rejecting summer gain and minimizing exposure to hot west summer sun). Numerous very low-energy buildings have been constructed at market cost simply by choosing a more economical to build and energy-saving form for the building. (Straube, 2012)

In a performance-based design approach, performance goals are developed during the initial stages of the design. The Integrated Design Process Guideline provides examples of how goals can be integrated into the design process (IEA 2003).

M. Deru and P. Torcellini, in **"Improving Sustainability of Buildings through a Performance-Based Design Approach"** propose a process that starts with a vision statement, such as:

"The project will design, construct, and operate a building that provides a healthy and productive work environment and minimizes the use of nonrenewable material and energy resources in a cost-effective manner"…………..??????????

3. PROBLEM DEFINITION

3.1 The issue of buildings' stock

Some simple numerical examples: In a total number of 4.5 millions dwellings, operate around 2-2.5 millions of boilers and burners, which means that 60.000 boilers and 120.000 burners should be replaced yearly. In a total number of 4.5 millions installed RAC split type, 400.000 should be replaced yearly. In a total number of 2 millions solar collectors 120.000 should be replaced yearly. In a total number of 4.5 millions dwellings, with an increase rate of 250.000 new dwellings per year, the last decade, at least 90.000 of them should be completely renovated yearly.

Year of construction	Buildings stock	Armed concrete buildings
Greece (in total)	3.990.970	2.992.312
Before 1945	606.143	88.269
1946-1980	2.164.072	1.758.488
1981-2000	1.220.755	1.145.555
Urban regions	1.950.060	1.687.680
Before 1945	180.871	54.612
1946-1980	1.093.242	989.355
1981-2000	675.947	643.713

3.2 The macro-economic feasibility of renovation measures

The energy savings achievable in a feasible way exceeds 25% per dwelling.
This fulfills the goal of 20%, as foreseen by Directive 2002/91/EC.
It leads to a total energy saving of 10.200 GWh yearly.
It is doable for a renovation rate of 120-150.000 dwellings per year over the next 10 years.
It involves investment costs of 1,2 - 1,5 billions € yearly (for one decade)
The annual financial value of saved energy (for the 1.200.000 dwellings) exceeds 750 millions € (in 2008 oil prices).
Macroeconomic profits: Multiple (growth in the building sector, employment, environmental gains etc)

3.3 Remarks

The most efficient way to reduce energy consumption in buildings, whilst improving thermal comfort and indoor air quality conditions, is to utilize any possibility for energy saving on heating and air-conditioning systems, either in new or in existing buildings.

This means:
A) Reinforced thermal insulation
B) High quality of windows and glazed surfaces
C) High efficiency heating and air-conditioning systems
D) Sun protection

Considering new buildings, the aforementioned mentioned parameters, should be implemented, in the conception-phase of building design, to perform in an integral way.

The successful implementation of these principles depends on:

A) In depth understanding of theoretical background

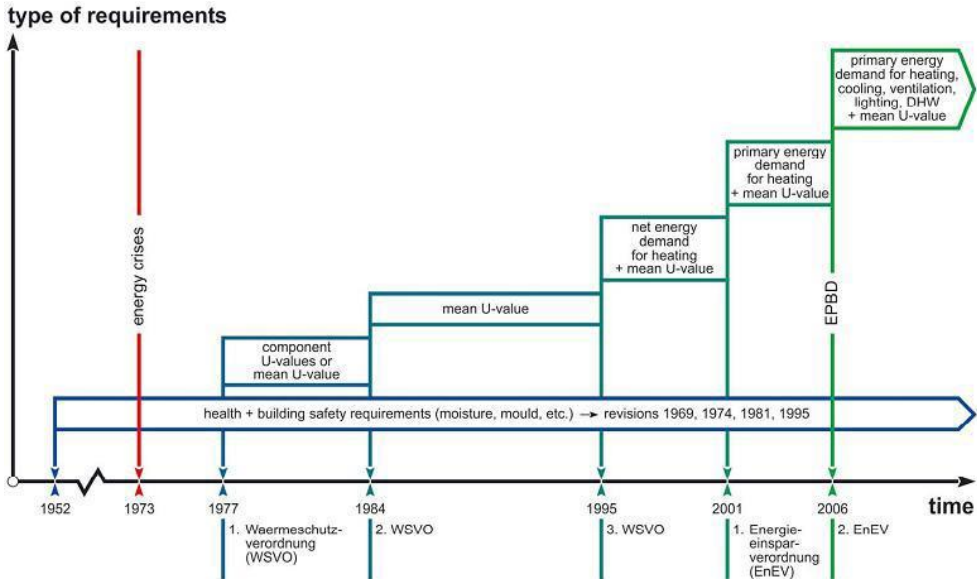
B) Awareness of contemporary technologies / know-how

C) Knowledge of new computational programs

D) Real comprehension of the need for multi-disciplinary collaboration

A high level of scientific and professional sufficiency is required. Sometimes, there is need for changing the professional attitude.

1979 TIR 2010 KENAK



The respective turn in regulations

The EPBD defines a nearly Zero-Energy Building as follows: [A nearly Zero-Energy Building is a] “building that has a very high energy performance..”. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby.”

In addition to the flexibility of the general EPBD definition for nZEB, several questions arise concerning the practicalities of nZEB definition:

- how to keep the nZEB definition sufficiently flexible so as to build upon existing low-energy standards and enable energy-positive buildings?
- how to properly define and set the share of renewable energy?
- how to determine the optimal balance between energy efficiency and renewable energy?

- how to forge the nZEB definition as a ‘silver bullet’ for reaching the same levels of energy and GHG reduction?
- how to link the nZEB definition to cost-optimality principles in order to have convergence and continuity?

Throughout Europe there is a large variety of concepts and voluntary standards for highly energy efficient buildings or even climate neutral buildings: passive house, zero-energy, 3-litre, plus energy, Minergie, Effinergie etc.

In addition, these definitions refer to different spheres: site energy, source energy, cost or emissions. Moreover there may be further variations in the requirements of the above standards depending on whether new or existing, residential or non-residential buildings are under consideration.

In a nutshell, the views on how nearly Zero-Energy Buildings should be defined, on which sphere to make the basis, as well as on which means and techniques are adequate, differ greatly.

Typically, low-energy buildings will encompass a high level of insulation, very energy efficient windows, a high level of air tightness and natural/mechanical ventilation with very efficient heat recovery to reduce heating/cooling needs.

Passive solar building design may boost their energy performance to very high levels by enabling the building to collect solar heat in winter and reject solar heat in summer and/or by integrating active solar technologies (such as solar collectors for domestic hot water and space heating or PV-panels for electricity generation).

In addition, other energy/resource saving measures may also be utilized, e.g. on-site windmills to produce electricity or rainwater collecting systems.

Today, more than half of the Member States do not have an officially recognized definition for low or Zero-Energy Buildings.

Various Member States have already set up long-term strategies and targets for achieving low-energy standards for new houses.

The existing low-energy building definitions among EU Member States have common approaches but also significant differences. Aggregation and improvement of the existing concepts is needed in order to align them to the nearly Zero-Energy Buildings requirements indicated by the EPBD and the Renewable Energy Directive.

Torcellini, Pless and Deru:

• Net Zero Site Energy: A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.

• Net Zero Source Energy: A source ZEB produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building’s total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.

• Net Zero-Energy Costs: In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.

• Net Zero-Energy Emissions: A net zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.

• Most of the low-energy building definitions in the European countries specify a maximum percentage of their national building standards' limit for primary energy consumption per square meter and year. However, there are variations between EU Member States on how to calculate and express the primary energy consumption of a building (e.g. using net or gross floor areas).

• The existing low-energy building definitions do not specifically indicate a certain share of renewables in the energy supply. The EPBD Recast indicates that energy required should be covered to a significant extent by renewable sources. Especially this lack of guidance on the share of renewables generates a mismatch between current regulations or definitions and the above-cited EPBD nearly zero-energy definition.

• There are various elements of existing concepts that can be used for the development of a nearly Zero-Energy Building definition, such as the principle of working with overarching targets accompanied by "sub-thresholds" on specific issues (such as requirements for maximum primary energy demand and additional limits for heating energy demand within the passive house concept).

Challenge No 1:

How and to what extent do current sectoral and overall targets of the EU regarding CO_2 emissions, energy efficiency, renewable energies and other indicators affect the ambition level and set-up of a nearly Zero-Energy Building definition? Implication for the nZEB definition If EU countries want to meet the 2050 targets for CO_2 reduction, then the nZEB requirements for new buildings also have to include nearly zero carbon emissions below approx. 3 $kgCO_2/m^2yr$ *. A weaker ambition for new buildings between 2021 and 2050 would necessarily lead to an even higher and almost unrealistic savings requirement of "90% plus" for the renovation of today's building stock.

Challenge No 2:

How different are the solutions between nearly zero CO_2 and nearly zero (primary) energy solutions for individual buildings and what are the implications for a suitable definition of nZEBs?

The first nZEB implication identified is the need for a consistent definition, which should contribute at the same time to both energy and CO_2 emission reductions. Hence, the minimum requirements for the energy performance of the building should use an energy indicator that can properly reflect both energy and CO_2 emissions of the building as the reduced energy consumption should lead to a proportional reduction of CO_2 emissions.

In general, the primary energy use of a building accurately reflects the depletion of fossil fuels and is sufficiently proportional to CO_2 emissions. Proportions are only distorted when nuclear electricity is involved. Nevertheless, if a single indicator is to be adopted, then the energy performance of the building should be indicated in terms of primary energy, as in line with current EPBD. However, to reflect the climate relevance of a building's operation, CO_2 emissions should be added as supplementary information.

Challenge No 3:

Which choices should be made within a definition regarding time disparities (e.g. daily vs. annual balance) and local disparities (e.g. on-site vs. off-site production) between produced and consumed energy? Implication for the nZEB definition The nZEB definition should properly deal with local and temporal disparities of renewable energy production. This is necessary in order to, on one hand, maximise the renewable energy share and the emission reductions and ensure a sustainable development of the local heating and cooling systems. Therefore the nZEB definition should address the following:

As to local disparities, the most obvious and practical solution is to accept and count all on-site, nearby and off-site production from renewable energy sources when calculating the primary energy use. Allowing for only on-site and nearby renewable energy production could be a considerable barrier in implementing nZEBs. Thus the nZEB definition should be flexible and adaptable to changes in local plans and strategies. For instance, a district heating connection should be mandatory for nZEBs when there are plans for a renewable powered district heating plant that offers supply at a reasonable price. Off-site renewable energy should be allowed as well because this offers more opportunities for 'green' energy production, opening and not restricting the future progress towards energy-positive buildings. However, off-site renewable energy has to be properly controlled and certified for avoiding fraud and double counting.

Temporal disparities in renewable energy supply may influence the associated GHG emissions of the building when off-site energy is used to compensate for periods with a lower renewable energy supply than the building's actual energy demand. Therefore, the period over which the energy balance of the building is calculated is important. The practical solution, offering at the same time a reasonable compromise, is to accept either monthly or annual balances. If annual balances are allowed, it will be necessary to introduce an additional verification methodology to take into account the associated GHG emissions of the energy supply over the period. The monthly energy balances are short enough to offer a reasonable guarantee for the emissions associated with the energy supplied to the building. In order to keep the concept as simple as possible it seems preferable and sufficient to use for the time being an annual balance, but to leave the option open for a more accurate yet demanding monthly energy balance in the future.

Challenge No 4:

How to ensure that a definition of nearly Zero-Energy Buildings avoids lock-in effects and allows the concept to be expanded later towards energy-positive buildings?

Implication for the nZEB definition

In order to ensure maximum flexibility and to minimise the risk of lock-in situations the nZEB definition should take into account the following:

• The evaluation of the buildings energy performance should be based on an annual balance but move towards a more accurate monthly balance in the future.

• The system boundaries should not be too tight, e.g. inclusion of renewable energy from the grid should be possible in specific cases when on-site/nearby capacities cannot be installed due to spatial and building geometry constrictions and/or weather conditions.

• The energy balance must take into account the quality of the energy and be assessed separately for electricity and heating. Hence, the quality of the energy production should be considered as being an important condition for avoiding a misleading nZEB concept with ineffective or counter-productive achievements.

Challenge No 5:

How can a definition be shaped to be applicable or transferable to different climates, building types, building traditions etc. in a way that reflects such differing circumstances and allows flexibility without leading to (too) complex rules?

A proper nZEB definition should take into account the climate, building geometry and usage conditions as follows:

• Climate: Two options are suggested for taking into account climate conditions in the nZEB definition:

- A first option is to calculate the energy requirement for an average European building located in an average European climate on the basis of the EU's 2050 climate target. This average energy requirement may then be corrected and adapted at national/regional level, e.g. by using the relation of national/regional vs. European cooling degree days (CDD)+ heating degree days (HDD).

- A second option is to calculate and impose a fixed value, being zero or very close to zero, and the same for each country and all over Europe. Such option would be chosen in the event that the first option appears to be too complicated or it will be necessary to have an absolute zero-energy balance for all new European buildings in order to reach the climate targets.

• Geometry:

It appears unfair for buildings with an "easy" shape to have to compensate for the unfavorable geometries of other buildings. Hence, for new buildings differences in geometry do not seem to be a striking argument for differences in energy requirements (e.g. in kWh/m^2yr) and the requirements should therefore be independent of geometry.

On the other hand, for the existing building stock this might be seen differently and the geometry aspects should be further analysed in order to avoid additional unfair burdening of the building owners.

• Usage:

All residential buildings should meet the same requirements as they typically have the same usage patterns. In addition, non-residential buildings with a similar usage pattern as residential buildings may still have the same requirements as residential buildings. The other non-residential buildings should be classified in as few categories as possible (following the main criteria of indoor temperature, internal heat gains, required ventilation etc.) and should have particular energy performance requirements.

Challenge No 6:

Should a definition of nearly Zero-Energy Buildings and related thresholds include or exclude household electricity (plug load) and in which way could this be done?

For providing convincing guidance on a nearly Zero-Energy Buildings definition, it may well be questioned if the EPBD lists all the relevant energy uses that are actually related to the ultimate goal of minimising building related CO2 emissions.

Based on an extensive analysis, the following is proposed:

1.

According to the EPBD only the energy use of equipment providing some selected “building services” which are heating, cooling, ventilation and lighting is to be considered in an nZEB definition.

Nevertheless there is some further integrated equipment providing building services, which may be even mandatory by law in most of the Member States, but which is missing in the EPBD and thus should be a part of it.

For example lifts and fire protection systems are not within the scope of the nZEB definition from the EPBD, but are part of the default ‘building services’.

2.

At this point in time, including electricity for appliances in the definition of nZEB is not recommended, because it is not in the current scope of the EPBD. However, in the long run, it is advisable to complement the energy uses currently mentioned in the EPBD by all other energy uses in the buildings.

Household electricity or electricity for appliances should be included in a future version of the EPBD, e.g. via a given value per person or m² (similar to the approach regarding the need for domestic hot water in current regulations) and consequently in the nZEB definition.

3.

To achieve a sustainable nZEB definition it may be important to take into account all the energy uses of a building for two main reasons:

- In today's very low-energy or passive houses the amount of household electricity or electricity for appliances respectively has the same order of magnitude as that needed for space heating/cooling and domestic hot water. The same is true for the technical systems providing building services.

- In Europe, on average, electricity consumption represents comparatively high amounts of primary energy consumption and related carbon dioxide emissions. The same goes for energy use in the construction of the building and its supply systems as well as for disposal of the building.

Challenge No 7:

Should a definition of nearly Zero-Energy Buildings and related thresholds include or exclude the production and disposal stage of building elements, components and systems and in which way could this be done?

A life-cycle assessment (LCA) approach for nZEB is definitely far beyond the current intention of the EPBD, but might be in a future recast. There are some practical recommendations to be considered for the time being:

• Energy consumption during the construction and disposal phases of a building becomes more important the more the energy consumption during the use phase decreases.

• Due to insufficient consistency of results from different LCA tools it may be too early to require LCA information as part of a threshold value. Nevertheless, in principle, it would make sense to include LCA information in the evaluation of a building's energy performance.

• A practical solution for the near future would be to estimate the energy need for production and disposal and require an informative mention of this value in addition to the indicator(s) reflecting the energy performance of the building.

Including the information regarding energy consumption during the phases of construction and disposal of a building will underline the importance of each life cycle phase's energy consumption.

However, for the time being it is not suggested that life cycle energy consumption should be included within the scope of the EPBD.

Challenge No 8:

Should it be possible within the definition of nearly Zero-Energy Buildings (regarding demand side and supply side) to look at groups of buildings rather than at a single building?

The EPBD clearly focuses on the energy performance of individual buildings. However, there may be good reasons to address a group of buildings and to have a common energy balance for them.

For assessing the opportunity of considering groups of buildings instead of a single building, the energy demand and the energy supply need to be analyzed separately.

As to the energy demand side, it may be a solution to compensate specific disadvantageous circumstances affecting one or a few selected buildings within a group of buildings (e.g. shading from landscape and thereby reduced solar gains) that do not allow each of these selected buildings to achieve a required very low energy demand with an acceptable level of effort. However, this would mean that the owner of a building which is part of such a pool would depend on what is actually built and maintained by other owners.

Apparently the situation is easier when having one owner for the whole new settlement, e.g. a building complex owned and rented by a real-estate company. However, especially in the case of new buildings, there seems to be little evidence to explain why a certain

required threshold should not be reached at the level of the individual building; the energy related or financial synergies from pooling buildings are not obvious. Consequently, there are no sufficiently strong reasons for clustering buildings.

• As to the energy supply side, it is clearly within the EPBD scope to use nearby/on-site central systems as an alternative to individual systems per building. Such central supply can yield benefits e g. in terms of investment savings, better efficiency and better possibilities for seasonal storage.

Challenge No 9:

What guidance can/needs to be given regarding the balance of energy efficiency and renewable energy within the nearly Zero-Energy Buildings definition?

It is necessary and also in line with the EPBD's nZEB definition to have a threshold for maximum energy demand as well as a requirement for the minimum percentage of renewables. For this reason, the renewable energy share should take into account only active supply systems such as solar systems, pellet boilers etc.

The passive use of renewable energy, e.g. passive solar gains, is an important design element of nearly Zero-Energy Buildings, but it seems logical - and also in line with EPBD-related CEN standards - to take these into account for the reduction of gross energy needs.

A threshold for energy demand could be set for each country in a given corridor, defined top-down at EU level according to the needs imposed by longer term climate targets and climate adjusted at country/regional level, e.g. based on HDD/ CDD.

The minimum share of renewables to cover the remaining nearly zero or very low energy demand of the building might be chosen in the range of 50%-90% in order to be consistent with EU energy and climate targets. Moreover, there are two more reasons for choosing a compulsory range of 50%-90%:

• The proposed range is in line with the nZEB definition from EPBD which is asking that the energy demand of the building be covered from renewable sources to a "very significant extent".

• The proposed range is likely to satisfy all the potential requirements for achieving the overarching targets for energy or GHG respectively.

Challenge No 10:

Is there a necessary or optional link between the principle of cost-optimality and the concept of nearly Zero-Energy Buildings within the EPBD recast and what could be the implications?

The recast EPBD stipulates that the EU Member States shall ensure minimum energy performance requirements for buildings to be set 'with a view to achieving cost-optimal levels'. Whereas the Commission is to provide the comparative framework cost-optimal methodology, each EU Member State has to do the calculations at country level, to compare the results with its energy performance requirements in force and to improve those requirements accordingly if necessary.

Challenge No 10:

Beyond delivering information for the update of current requirements over the coming years, the costoptimal methodology is suitable for gradually steering cost-optimal levels towards nZEB levels by 2021.

Indeed, the cost-optimal methodology may be used, for instance, to calculate the needed financial support (soft loans, subsidies etc.) and market developments (cost reduction for certain technology etc.) for facilitating a smooth and logical transition from today's energy performance requirements towards nZEB levels in 2021.

Consequently, when fixing a threshold for the energy demand of a nZEB, it is recommended to leave some freedom for placing this threshold within a certain corridor, which could be defined as follows:

• The upper – least ambitious - limit, defined by the energy demand of different building types, would result from applying the cost-optimal levels according to Article 5 of the EPBD recast.

• The lower – most ambitious - limit of the corridor, would be set by the best available technology that is freely available and well introduced on the market, e.g. as, currently, triple glazing for windows.

Markets	Required growth factor	Current market size	Unit
Insulation materials	2-3	2 010	Mio EUR
Ventilation systems with heat recovery	8-10	130 000	units
Triple glazed windows	>10	1 500 000	m^2
Heat pumps	2-3	185 000	units
Pellet boilers	2-3	43 000	units
Solar thermal systems	2-3	3 700 000	m^2

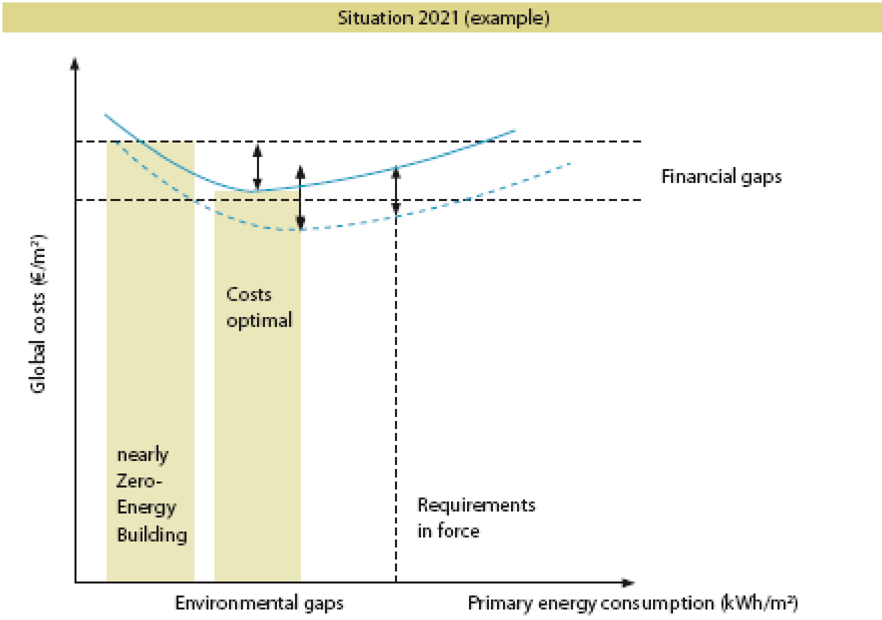
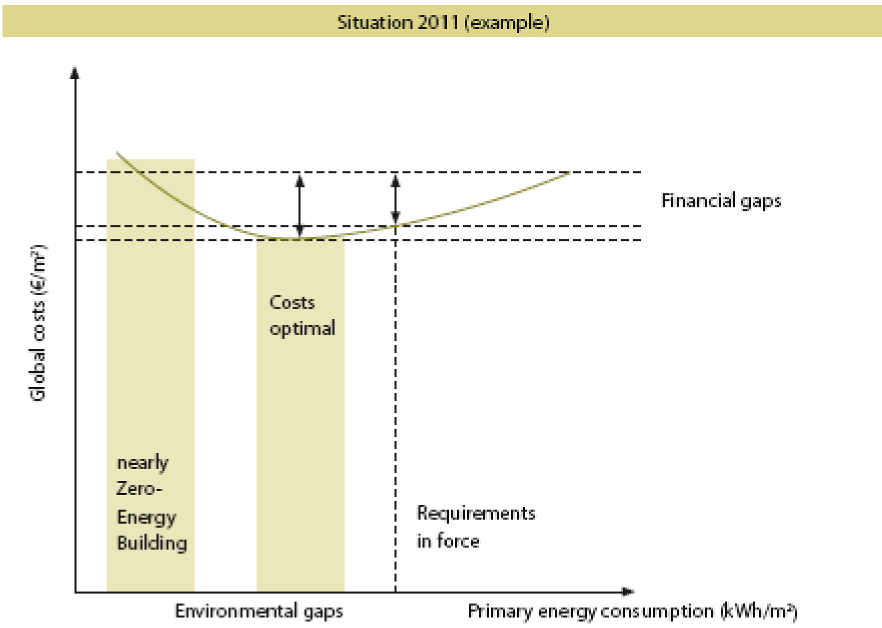


Figure 19: Relationship between cost-optimality and nearly Zero-Energy Buildings in 2011 and 2021



[11] Assuming an extra investment of EUR 39 billion per year (see previous chapter) and an average turnover in the EU construction industry of EUR 113,000 (in 2008) per person and year.

Sustainable Built Environment

□Designing and constructing human buildings

□In viable cities

□Making sure that this will remain like this for the generations to come

Achieving and measuring Sustainability in the built environment calls for:

Concepts

Life Cycle Thinking concept LCTt: LCT considers the cradle-to-grave implications of any action. It expands the scope of their responsibility to include environmental implications along the entire life cycle of the product, process or activity.
Life Cycle Management LCM: LCM aims at achieving continuous environmental improvement from a life cycle perspective. It can make use of existing environmental and other management systems and tools which include national or international standards and validated eco-efficiency indicators.
Industrial Ecology: Industrial Ecology is the multidisciplinary study of industrial systems and economic activities and their link to fundamental natural systems.
End of Life Management: The management of products at the time their functional life has ended. This concept focuses on the environmental aspects of a product when it enters the waste phase. Different stakeholders can be involved to EOL-management but the authorities have the greater responsibility for waste collection and treatment.

Environmental Tools

1. Life cycle Assessment **LCA**
2. Material input per unit of service **MIPS**
3. Environmental risk assessment **ERA**
4. Life cycle costing **LCC**
5. Total cost accounting **TCA**
6. Total cost accounting **TCA**
7. Cost benefit analysis **CBA**
8. Material flow accounting **MFA**
9. Cumulative Energy requirements analysis **CERA**
10. Analytical tools for ecodesign
11. Environmental input-output analysis **IOA**

Rating Systems

Rating systems are environmental and management tools focusing on the construction sector and targeting sustainability, as well as to economic and social benefits.

LEED and BREEAM are the most popular and mature rating systems. BREEAM certification process is tougher and needs as a rule more work compared to LEED.

It is a complex issue, involving many aspects:

- Adequate information is needed to support all these systems
- This information has to be provided on a national, regional and sometimes even local scale
- Results have to treated with caution, especially when they are “absolute” and not “relative”.

Zero-Energy Buildings: How Definition Influences Design
Depending on the ZEB definition, the results can vary substantially. Each definition has advantages and disadvantages, which are discussed below.

Net Zero Site Energy Building

A site ZEB produces as much energy as it uses, when accounted for at the site.
A site ZEB can be easily verified through on-site measurements, whereas source energy or emissions ZEBs cannot be measured directly because site-to-source factors need to be determined. An easily measurable definition is important to accurately determine the progress toward meeting a ZEB goal.
A limitation of a site ZEB definition is that the values of various fuels at the source are not considered.

A site ZEB has the fewest external fluctuations that influence the ZEB goal, and therefore provides the most repeatable and consistent definition. This is not the case for the cost ZEB definition because fluctuations in energy costs and rate structures over the life of a building affect the success in reaching net zero energy costs. Similarly, source energy conversion rates may change over the life of a building, depending on the type of power plant or power source mix the utility uses to provide electricity.
A building could be a site ZEB but not realize comparable energy cost savings.

Net Zero Source Energy Building
A source ZEB produces as much energy as it uses as measured at the source. To calculate a building's total source energy, both imported and exported energy are multiplied by the appropriate site-to-source energy factors. To make this calculation, power generation and transmission factors are needed.
This definition also depends on the method used to calculate site-to-source electricity energy factors.
The issue of unmanaged energy costs in a site ZEB is similar for a source ZEB. A building could be a source ZEB and not realize comparable energy cost savings. If peak de-

mands and utility bills are not managed, the energy costs may or may not be similarly reduced.

Net Zero Energy Cost Building
A cost ZEB receives as much financial credit for exported energy as it is charged on the utility bills. The credit received for exported electricity (often referred to net energy generation) will have to offset energy, distribution, peak demand, taxes, and metering charges for electricity and gas use. A cost ZEB provides a relatively even comparison of fuel types used at the site as well as a surrogate for infrastructure. Therefore, the energy availability specific to the site and the competing fuel costs would determine the optimal solutions. However, as utility rates can vary widely, a building with consistent energy performance could meet the cost ZEB goal one year and not the next.
For commercial buildings, a cost ZEB is typically the hardest to reach, and is very dependent on how a utility credits net electricity generation and the utility rate structure the building uses. One way to reach this goal in a small commercial building might be to use a utility rate that minimizes demand charges.

Net Zero Energy Emissions Building
An emissions-based ZEB produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources. An on-site emission ZEB offsets its emissions by using supply-side options 1 and 2 in Table 1. If an all-electric building obtains all its electricity from an off-site zero emissions source (such as hydro, nuclear, or large scale wind farms), it is already zero emissions and does not have to generate any on-site renewable energy to offset emissions. However, if the same building uses natural gas for heating, then it will need to generate and export enough emissions-free renewable energy to offset the emissions from the natural gas use. Purchasing emissions offsets from other sources would be considered an off-site zero emissions building.
Success in achieving an emissions ZEB depends on the generation source of the electricity used.

Table 3. ZEB Definitions Summary

Defini-tion	Pluses	Minuses	Other Issues
Site ZEB	• Easy to implement. • Verifiable through on-site measurements. • Conservative approach to achieving ZEB. • No externalities affect performance, can track success over time. • Easy for the building community to understand and communicate. • Encourages energy-efficient building designs.	• Requires more PV export to offset natural gas. • Does not consider all utility costs (can have a low load factor). • Not able to equate fuel types. • Does not account for nonenergy differences between fuel types (supply availability, pollution).	
Source ZEB	• Able to equate energy value of fuel types used at the site. • Better model for impact on national energy system. • Easier ZEB to reach.	• Does not account for nonenergy differences between fuel types (supply availability, pollution). • Source calculations too broad (do not account for regional or daily	• Need to develop site-to-source conversion factors, which require significant amounts of information to define.

		variations in electricity generation heat rates). • Source energy use accounting and fuel switching can have a larger impact than efficiency technologies. • Does not consider all energy costs (can have a low load factor).	
Cost ZEB	• Easy to implement and measure. • Market forces result in a good balance between fuel types. • Allows for demand-responsive control. • Verifiable from utility bills.	• May not reflect impact to national grid for demand, as extra PV generation can be more valuable for reducing demand with on-site storage than exporting to the grid. • Requires net-metering agreements such that exported electricity can offset energy and nonenergy charges. • Highly volatile energy rates make for difficult tracking over time.	• Offsetting monthly service and infrastructure charges require going beyond ZEB. • Net metering is not well established, often with capacity limits and at buyback rates lower than retail rates.
Emissions ZEB	• Better model for green power. • Accounts for nonenergy differences between fuel types (pollution, greenhouse gases). • Easier ZEB to reach.	• Need appropriate emission factors.	

4. CONTRIBUTION

METHODOLOGY

This study has the following steps:

- Identify the methodology
- Choose the buildings
- Present the general characteristics of the selected buildings
- Energy audit for each building – Input data to TEE-KENAK software
- Results of the energy audit – Output
- Analysis and discussion of the results
- Evaluation and assessment

The calculation procedure will be structured according to the following steps:

a) Calculation of the building net energy demand (energy needs for heating and cooling), together with that for domestic hot water, ventilation and lighting (only for the non-residential buildings)

b) Calculation of the building's delivered energy (final energy consumption, etc.)

c) Calculation of the overall energy use and the overall energy performance indicators (primary energy, CO_2 emissions, etc.)

d) Evaluation of the energy performance of the building

For every building zone and each calculation period – month calculate:

1. The heat transfer by transmission
2. The heat transfer by ventilation
3. The internal heat sources
4. The solar heat gains
5. The dynamic parameters
6. The energy need for heating Q_{NH} and for cooling Q_{NC}
7. The total system energy consumption for heating Q_{sysH} and for cooling Q_{sysC}

Calculation of the total system energy consumption for heating

Calculation of the total system energy consumption for cooling

Calculation of the total system energy consumption for lighting

Calculation of the total system energy consumption for appliances

Calculation of the DHW energy consumption

To study the impact of these ZEB definitions, this dissertation will examine five public buildings in Kalamaria.

These buildings are:

1. The municipality central offices building (2 storey, before 1955, restored)
2. The cultural organization building (2 storey, before 1955, restored)
3. A primary education school building (2 storey, before 1955)
4. A social services, disabled-school and library building (2 storey, before 1955)
5. A social services offices and nursery building (2 storey, before 1955)

Building A - The municipality central offices building

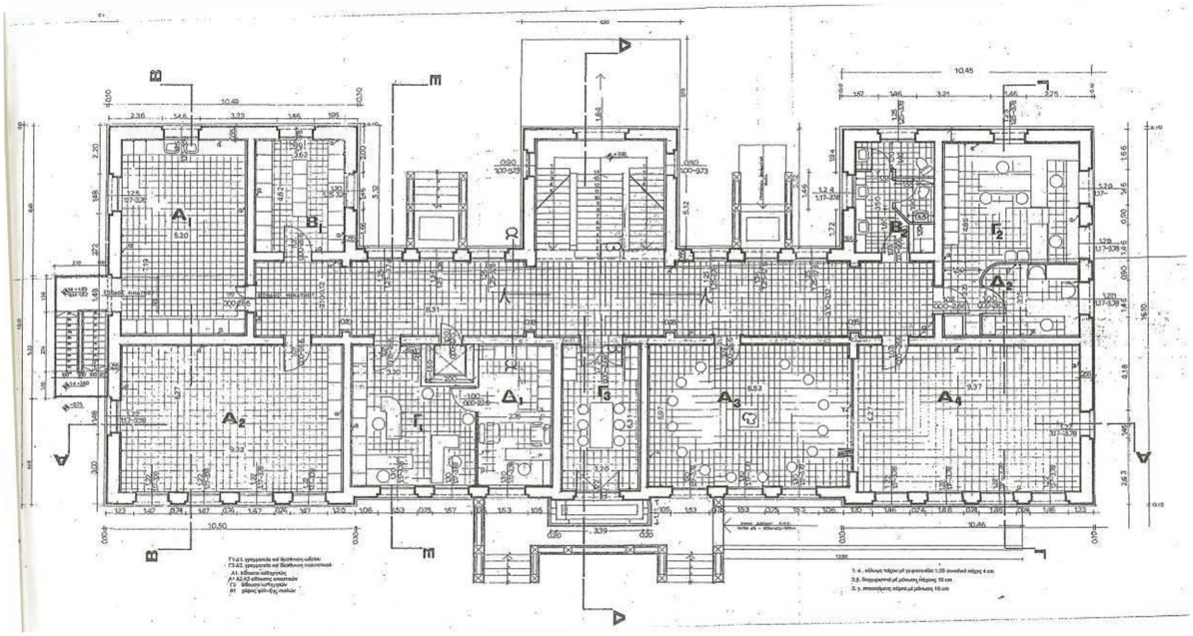
General characteristics

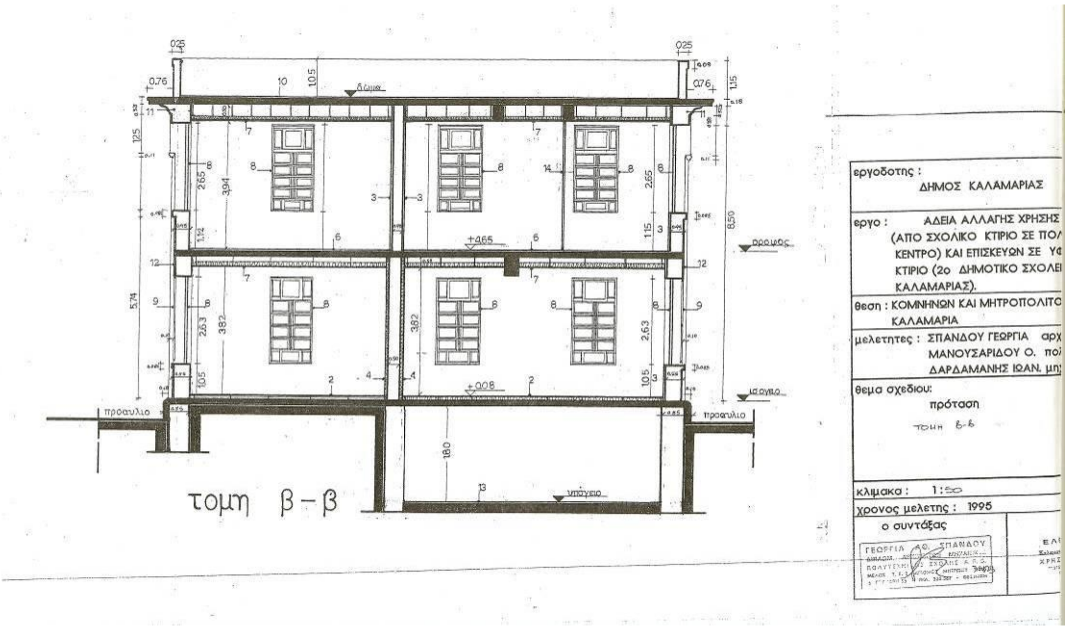
Google-earth. The building's orientation is SE - 20^o inclination

Front façade. South – East orientation. Foto at 8.30 in the morning.

WS façade. Emergency exit.

NW façade – Back entrance.


Α1
Α2
Α3
Α4
Β1
Β2
Γ1
Γ2
Γ3
Δ1
Δ2


δώμα
δρόμος
ισόγειο
υπόγειο
προαύλιο
τομη β – β
εργοδοτης :
ΔΗΜΟΣ ΚΑΛΑΜΑΡΙΑΣ
εργο : ΑΔΕΙΑ ΑΛΛΑΓΗΣ ΧΡΗΣΗΣ
(ΑΠΟ ΣΧΟΛΙΚΟ ΚΤΙΡΙΟ ΣΕ ΠΟΛ
ΚΕΝΤΡΟ) ΚΑΙ ΕΠΙΣΚΕΥΩΝ ΣΕ ΥΦ
ΚΤΙΡΙΟ (2ο ΔΗΜΟΤΙΚΟ ΣΧΟΛΕΙ
ΚΑΛΑΜΑΡΙΑΣ).
θεση : ΚΟΜΝΗΝΩΝ ΚΑΙ ΜΗΤΡΟΠΟΛΙΤΟ
ΚΑΛΑΜΑΡΙΑ
μελετητες : ΣΠΑΝΔΟΥ ΓΕΩΡΓΙΑ αρχ
ΜΑΝΟΥΣΑΡΙΔΟΥ Ο. πολ
ΔΑΡΔΑΜΑΝΗΣ ΙΩΑΝ. μηχ
θεμα σχεδιου:
πρόταση
τομη β-β
κλιμακα : 1:50
χρονος μελετης : 1995
ο συντάξας

Interior space.

Staircase – roof ending. Fan coils. Cooling system.

ΦΥΛΛΟ ΣΥΝΤΗΡΗΣΗΣ ΚΑΙ ΡΥΘΜΙΣΗΣ ΤΩΝ ΕΓΚΑΤΑΣΤΑΣΕΩΝ ΚΕΝΤΡΙΚΗΣ ΘΕΡΜΑΝΣΗΣ

1. ΣΤΟΙΧΕΙΑ

1. Διεύθυνση: Κομνηνών 58 - ΚΑΛΑΜΑΡΙΑ
2. Χρήση ακινήτου: ΝΕΟ ΔΗΜΑΡΧΕΙΟ
3. Χρήστης ακινήτου: ……
4. Ονομ. Ισχύς Λέβητα: 315.000kcal/h kW
5. Τύπος Λέβητα: ΚΑΛΟΘΕΡΜΙΚΗ
6. Ονομ. Ισχύς καυστήρα: 118-338kW
7. Τύπος Καυστήρα: BALTUR 2001
8. Είδος Καυσίμου: Φυσικό Αέριο
9. Παροχή: ……
10. Ετήσια κατανάλωση Καυσίμου : ……

2. ΕΡΓΑΣΙΕΣ

Α/Α	ΕΙΔΟΣ ΕΡΓΑΣΙΑΣ	
1.	ΚΑΘΑΡΙΣΜΟΣ ΛΕΒΗΤΑ	X
2.	ΚΑΘΑΡΙΣΜΟΣ ΚΑΠΝΟΔΟΧΟΥ	X
3.	ΚΑΘΑΡΙΣΜΟΣ Ή ΑΝΤΙΚΑΤΑΣΤΑΣΗ ΜΠΕΚ	X
4.	ΚΑΘΑΡΙΣΜΟΣ ΡΥΘΜΙΣΗ ΗΛΕΚΤΡΟΔΙΩΝ ΙΟΝΙΣΜΟΥ ΣΠΙΝΘΗΡΑ	X
5.	ΡΥΘΜΙΣΗ ΑΝΑΛΟΓΙΑΣ ΑΕΡΑ-ΚΑΥΣΙΜΟΥ	X
6.	ΕΛΕΓΧΟΣ ΔΙΑΡΡΟΩΝ ΚΑΥΣΙΜΟΥ	X
7.	ΕΛΕΓΧΟΣ ΔΙΑΡΡΟΩΝ ΚΑΥΣΑΕΡΙΩΝ	X
8.	ΔΟΚΙΜΗ ΛΕΙΤΟΥΡΓΙΑΣ ΣΥΣΤΗΜ. ΑΝΙΧΝΕΥΣΗΣ ΑΕΡΙΟΥ (αν υπάρχει)	
9.	ΔΟΚΙΜΗ ΛΕΙΤΟΥΡΓΙΑΣ ΑΣΦΑΛ/ΚΩΝ ΣΥΣΤ/ΤΩΝ ΛΕΒΗΤΑ-ΚΑΥΣΤΗΡΑ	X
10.	ΜΕΤΡΗΣΗ ΚΑΙ ΑΝΑΛΥΣΗ ΚΑΥΣΑΕΡΙΩΝ	X
11.	ΑΛΛΕΣ ΕΡΓΑΣΙΕΣ	

* ΟΙ ΕΡΓΑΣΙΕΣ ΣΗΜΕΙΩΝΟΝΤΑΙ ΜΕ 'X'

3. ΜΕΤΡΗΣΕΙΣ

1. ΘΕΡΜΟΚΡΑΣΙΑ ΚΑΥΣΑΕΡΙΩΝ 245.5 °C
2. ΘΕΡΜΟΚΡΑΣΙΑ ΛΕΒΗΤΟΣΤΑΣΙΟΥ 15 °C
3. ΜΟΝΟΞΕΙΔΙΟ ΤΟΥ ΑΝΘΡΑΚΑ 0 ppm
4. ΟΞΕΙΔΙΑ ΤΟΥ ΑΖΩΤΟΥ …… ppm
5. ΔΙΟΞΕΙΔΙΟ ΤΟΥ ΑΝΘΡΑΚΑ 9,24 %
6. ΔΙΟΞΕΙΔΙΟ ΤΟΥ ΟΞΥΓΟΝΟΥ 4,7 %
7. ΔΕΙΚΤΗΣ ΑΙΘΑΛΗΣ (BACHARACH) 0
8. ΕΛΚΥΣΜΟΣ 0,17 mbar
9. ΠΙΕΣΗ ΑΝΤΛΙΑΣ ΚΑΥΣΤΗΡΑ …… bar
10. ΠΙΕΣΗ ΤΡΟΦΟΔΟΣΙΑΣ ΑΕΡΙΟΥ [illegible] mbar
11. ΘΕΡΜΟΚΡΑΣΙΑ ΝΕΡΟΥ ΛΕΒΗΤΑ 65 °C
12. ΣΥΝΤΕΛΕΣΤΗΣ λ 1,29

4. ΥΠΟΛΟΓΙΣΜΟΙ

1. ΕΣΩΤΕΡΙΚΟΣ ΒΑΘΜΟΣ ΑΠΟΔΟΣΗΣ 88,6 %
2. ΑΠΩΛΕΙΕΣ ΚΑΥΣΑΕΡΙΩΝ …… %
3. ΠΑΡΟΧΗ ΚΑΥΣΙΜΟΥ …… kg/h m^3/h
4. ΘΕΡΜΙΚΗ ΦΟΡΤΙΣΗ ΛΕΒΗΤΑ …… %

Οι μετρήσεις δείχνουν ότι είναι:
ΕΝΤΟΣ X ΕΚΤΟΣ ☐
Των προβλεπόμενων ορίων

5. ΠΑΡΑΤΗΡΗΣΕΙΣ

……

**ΣΕ ΠΕΡΙΠΤΩΣΗ ΑΔΥΝΑΜΙΑΣ ΡΥΘΜΙΣΗΣ ΤΟΥ ΚΑΥΣΤΗΡΑ ΣΤΑ ΠΡΟΒΛΕΠΟΜΕΝΑ ΑΠΟ ΤΗΝ ΝΟΜΟΘΕΣΙΑ ΟΡΙΑ ΝΑ ΑΝΑΦΕΡΟΝΤΑΙ ΛΕΠΤΟΜΕΡΩΣ ΟΙ ΑΙΤΙΕΣ

6. ΣΤΟΙΧΕΙΑ ΣΥΝΤΗΡΗΤΗ

Α. ΚΟΥΚΙΩΤΗΣ - Μ. ΠΕΓΙΟΣ & ΣΙΑ Ο.Ε.
ΚΛΙΜΑ Service
ΕΦΑΡΜΟΓΕΣ ΚΛΙΜΑΤΙΣΜΟΥ & ΘΕΡΜΑΝΣΗΣ
ΜΕΛΕΝΙΚΟΥ 50 (ΒΟΥΛΓΑΡΗ) 542 48 ΘΕΣ/ΝΙΚΗ
ΤΗΛ. & FAX: 2310-334.844
Α.Φ.Μ. 999978383-Δ.Ο.Υ. Ζ' ΘΕΣ/ΚΗΣ

1. ΗΜΕΡΟΜΗΝΙΑ ΣΥΝΤΗΡΗΣΗΣ 14-8-2012
2. Ο ΣΥΝΤΗΡΗΤΗΣ (ΥΠΟΓΡΑΦΗ) ΚΟΥΚΙΩΤΗΣ ΑΘΑΝΑΣΙΟΣ
3. Ο ΥΠΕΥΘΥΝΟΣ ΤΟΥ ΛΕΒΗΤΟΣΤΑΣΙΟΥ (ΔΙΑΧΕΙΡΙΣΤΗΣ-ΘΥΡΩΡΟΣ Κ.Λ.Π.) ……

Building General

Usage	OFFICE BUILDING		**Built before 1955. Used as a school building. Restored in 1995. Changed use as central offices of the Municipality of Kalamaria**			
Total floor area	616,68	m^2	Total volume	5.550,16	m^3	
Heated floor area:	616,68	m^2	Heated volume	5.550,16	m^3	
Cooled floor area	616,68	m^2	Cooled volume	5.550,16	m^3	
Number of floors	2	m	Typical floor height	4,5	m	Basement height
Number of thermal zones	1					
Number of unconditioned spaces	4					

RESULTS

Primary energy consumption [kWh/m^2]	Building
Heating	266,10
Cooling	95,70
Domestic Hot Water	0,00
Lighting	114,20
Renewable Energy Sources	0,00
Total	475,90
Ranking (Energy Class)	**D**

Energy source	Fuel Consumption [kWh/m^2]	CO_2 Emissions [kg/m²]
Electricity	85,50	84,60
Oil	0,00	0,00
Natural gas	204,30	40,00
Other fossil fuels	0,00	0,00
Solar	0,00	0,00
Biomass	0,00	0,00
Geothermal	0,00	0,00
Other RES	0,00	0,00
Total	289,70	124,60

Energy demand [kWh/m^2]	Jan	Feb	Mar	Apr	May	Jun
Heating	57,20	36,60	14,50	5,80	0,00	0,00
Cooling	0,00	0,00	0,00	0,00	0,00	11,80
Domestic Hot Water	0,00	0,00	0,00	0,00	0,00	0,00

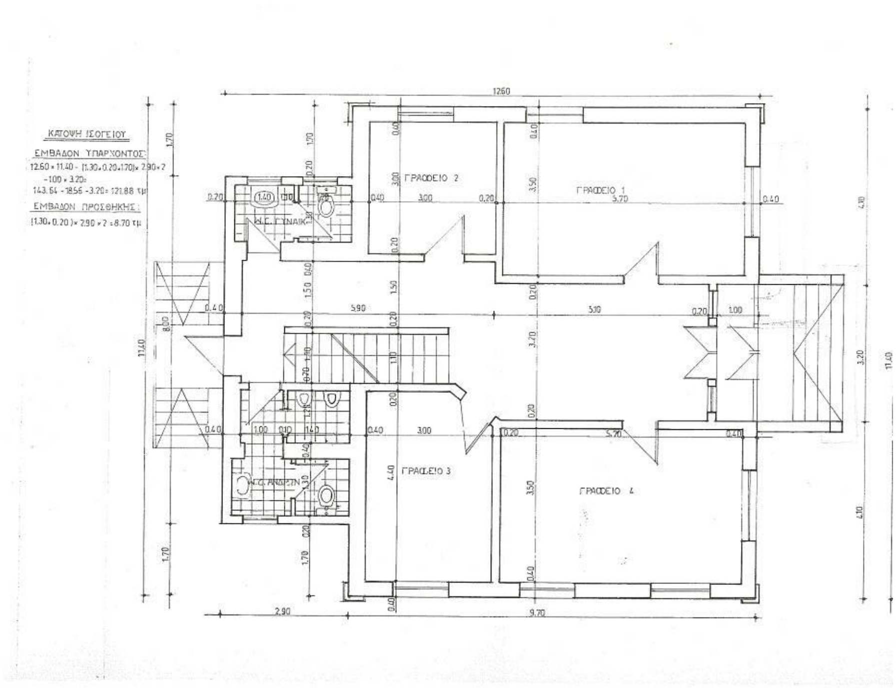
Final energy consumption [kWh/m^2]	Jan	Feb	Mar	Apr	May	Jun
Heating	67,80	40,10	21,90	9,30	0,00	0,00
Cooling	0,00	0,00	0,00	0,00	0,00	5,80
Lighting	3,30	3,00	3,30	3,20	3,30	3,20
Total	71,10	43,10	25,20	12,50	3,30	9,00

Operational cost [€]	17641,50

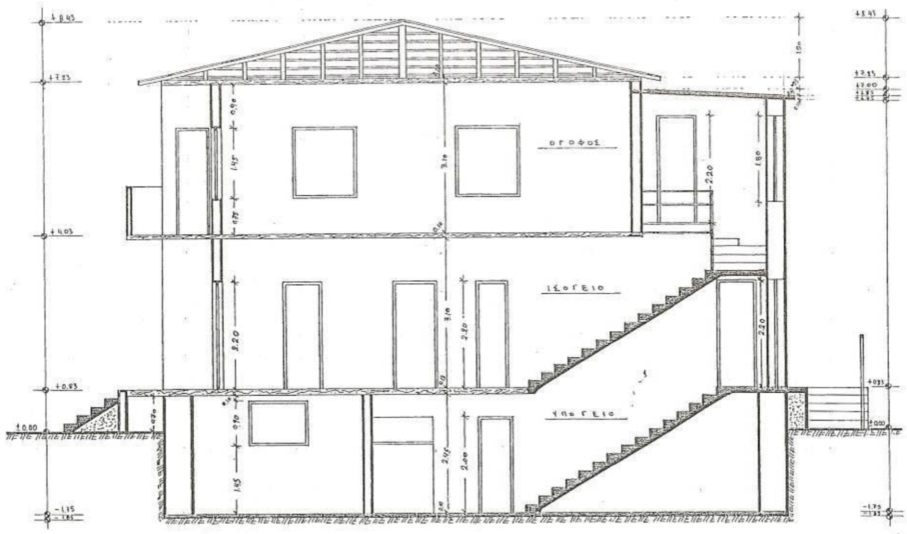
Building B - The cultural organization building

General characteristics

Google-earth. The building's orientation is SE - 20^{o} inclination



GROUND FLOOR PLAN



CROSS SECTION

Front façade. North – East orientation. SW façade – Back entrance.

Cooling tower.

Interior space.

POWER *	**KW**	**h/year**	**KWh**	
TOTAL ELECTRIC POWER	60,00			
TOTAL THERMAL POWER	45,84			**Hours / day = 8**
TOTAL POWER FOR HEATING	45,84			
TOTAL POWER FOR COOLING	50,00			
TOTAL POWER FOR LIGHTING	9,10			

			CONSUMPTION / year	
MECHANICAL SYSTEMS *	**KW**	**h/year**	**KWh**	
COOLING TOWER	50,00	450	22.500	
FAN COILS	2,10	1.450	3.045	
COOLING – HEATING PUMPS	1,50	1.000	1.500	
LIGHTING	2,30	1.300	2.990	
COMPUTERS	4,00	1.300	5.200	
			35.235	**TOTAL CONSUMPTION**

* Source: the Technical Dep. of the Municipality of Kalamaria.

Building General

Usage	**OFFICE BUILDING**		**Built before 1955. Used as a music school building. Restored in 1995. Changed use as offices of the Cultural Organization of Kalamaria**				
Total floor area	130	m^2	Total volume	780,00	m^3		
Heated floor area:	130	m^2	Heated volume	780,00	m^3		
Cooled floor area	130	m^2	Cooled volume	780,00	m^3		
Number of floors	2	m	Typical floor height	3	m	Basement height	1
Number of thermal zones	1						
Number of unconditioned spaces							

RESULTS

Primary energy consumption [kWh/m²]	Reference building	Building
Heating	145,40	702,80
Cooling	74,20	182,20
Domestic Hot Water	0,00	0,00
Lighting	123,50	139,20
Renewable Energy Sources	0,00	0,00
Total	343,10	1024,20
Ranking (Energy Class)		H

Final energy consumption [kWh/m²]	Jan	Feb	Mar	Apr	May	Jun
Heating	188,40	113,10	70,90	34,00	0,00	0,00
Cooling	0,00	0,00	0,00	0,00	0,20	9,00
Domestic Hot Water	4,10	3,70	4,10	3,90	4,10	3,90
Total	192,50	116,80	75,00	37,90	4,30	12,90

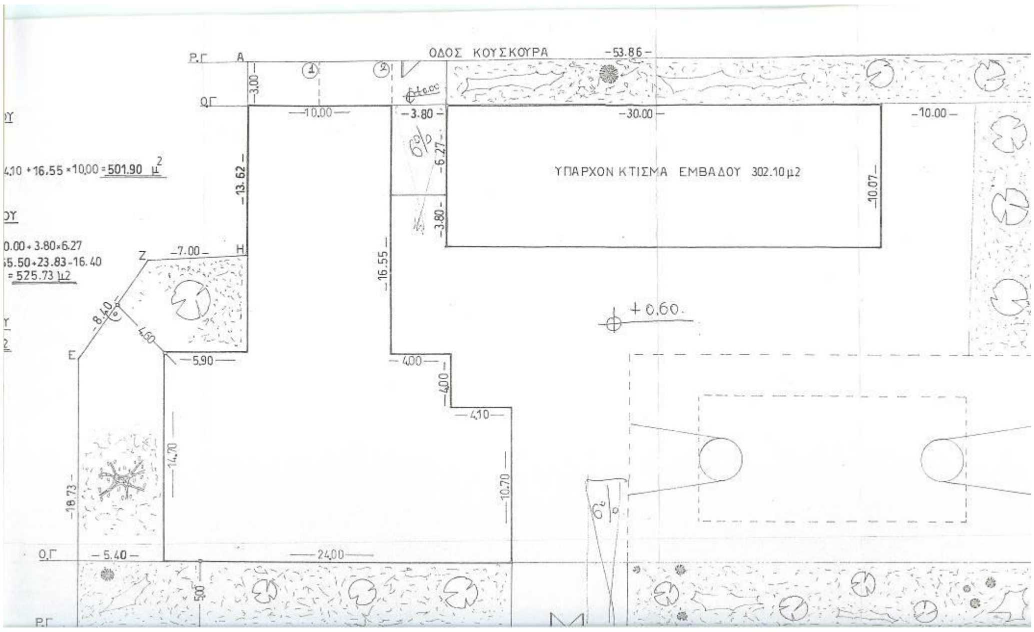
Operational cost [€]	
	7867,60

Energy source	Fuel Consumption [kWh/m²]	CO_2 Emissions [kg/m²]
Electricity	131,70	130,30
Oil	0,00	0,00
Natural gas	628,30	123,10
Other fossil fuels	0,00	0,00
Solar	0,00	0,00
Biomass	0,00	0,00
Geothermal	0,00	0,00
Other RES	0,00	0,00
Total	757,60	253,40

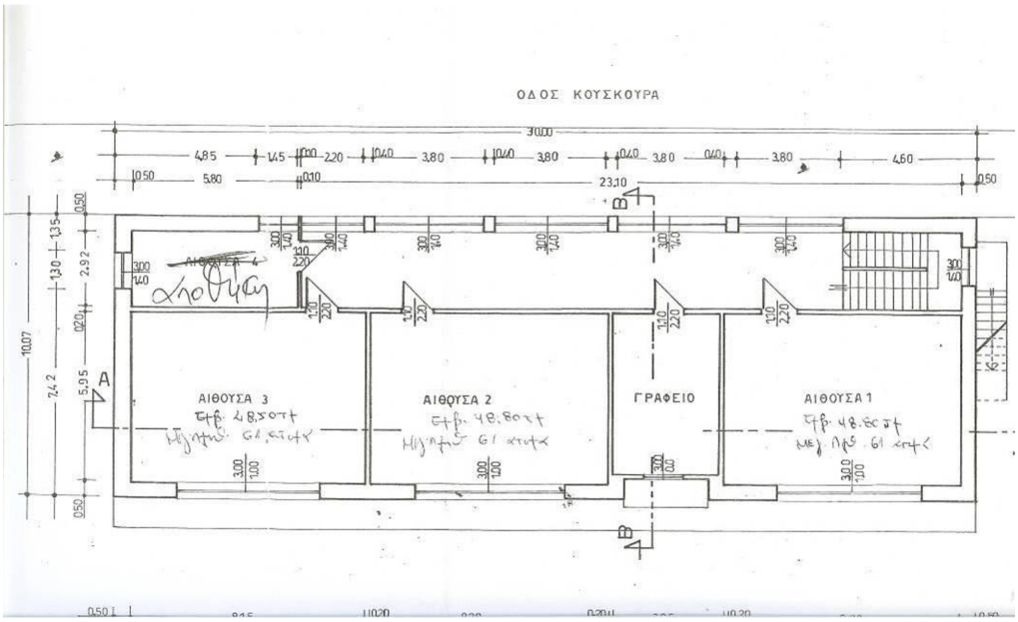
Building C - A primary education school building

General characteristics

Google-earth. The building's orientation is SE.


ΟΔΟΣ ΚΟΥΣΚΟΥΡΑ
ΥΠΑΡΧΟΝ ΚΤΙΣΜΑ ΕΜΒΑΔΟΥ 302.10μ2
+0.60
-53.86-
-30.00-
-10.00-
-3.80-
-13.62-
-16.55-
-10.07-
-10.70-
-24.00-
-5.40-
-18.73-
-7.00-
-5.90-
-4.10-
-14.70-
4,10 +16.55×10,00=501.90 μ2
=525.73 μ2


Γ' ΔΗΜΟΤΙΚΟΝ ΣΧΟΛΕΙΟΝ ΚΑΛΑΜΑΡΙΑΣ


ΟΔΟΣ ΚΟΥΣΚΟΥΡΑ
ΑΙΘΟΥΣΑ 3
ΑΙΘΟΥΣΑ 2
ΓΡΑΦΕΙΟ
ΑΙΘΟΥΣΑ 1

Building General

Usage	**SCHOOL BUILDING**		**Built before 1955. It was the first primary school of Kalamaria.**			
Total floor area	302,10	m^2	Total volume	2.114,70	m^3	
Heated floor area:	302,10	m^2	Heated volume	2.114,70	m^3	
Cooled floor area	151,05	m^2	Cooled volume	1.057,30	m^3	
Number of floors	2	m	Typical floor height	3,5	m	Basement height
Number of thermal zones	1					
Number of unconditioned spaces						

RESULTS

Primary energy consumption [kWh/m^2]	Reference building	Building
Heating	84,50	624,10
Cooling	0,50	0,50
Domestic Hot Water	0,00	0,00
Lighting	123,50	59,90
Renewable Energy Sources	0,00	0,00
Total	208,50	684,50
Ranking (Energy Class)		H

Energy source	Fuel Consumption [kWh/m^2]	CO_2 Emissions [kg/m²]
Electricity	73,70	72,90
Oil	0,00	0,00
Natural gas	579,30	113,50
Other fossil fuels	0,00	0,00
Solar	0,00	0,00
Biomass	0,00	0,00
Geothermal	0,00	0,00
Other RES	0,00	0,00
Total	608,10	186,40

Final energy consumption [kWh/m^2]	Jan	Feb	Mar	Apr	May	Jun	Jul
Heating	168,40	115,90	56,70	22,20	0,00	0,00	0
Cooling	0,00	0,00	0,00	0,00	0,10	0,00	0
Domestic Hot Water	2,30	2,30	2,30	2,30	2,30	0,00	0
Total	170,70	118,20	59,00	24,50	2,40	0,00	0

Operational cost [€]	15229,70

Building D - A library and disabled-school building

General characteristics

Google-earth. The building's orientation is SE.


ΠΑΙΔΙΚΗ ΒΙΒΛΙΟΘΗΚΗ

Building General

Usage	**PUBLIC SERVICES BUILDING (OFFICES AND NURSERY)**		**Built before 1955. Restored. It is used for offices (first floor) and nursery (ground floor).**			
Total floor area	260	m^2	Total volume	1.560,00	m^3	
Heated floor area:	260	m^2	Heated volume	1.560,00	m^3	
Cooled floor area	130	m^2	Cooled volume	780,00	m^3	
Number of floors	2	m	Typical floor height	3	m	Baser
Number of thermal zones	1					
Number of unconditioned spaces	0					

RESULTS

Primary energy consumption [kWh/m^2]	Reference building	Building
Heating	81,10	581,60
Cooling	122,60	284,80
Domestic Hot Water	59,60	70,10
Lighting	123,50	69,60
Renewable Energy Sources	0,00	0,00
Total	386,80	1006,00
Ranking (Energy Class)		Z

Energy source	Fuel Consumption [kWh/m^2]	CO_2 Emissions [kg/m^2]
Electricity	160,80	159,00
Oil	0,00	0,00
Natural gas	537,80	105,40
Other fossil fuels	0,00	0,00
Solar	0,00	0,00
Biomass	0,00	0,00
Geothermal	0,00	0,00
Other RES	0,00	0,00
Total	693,40	264,40

Final energy consumption [kWh/m^2]	Jan	Feb	Mar	Apr	May	Jun
Heating	153,50	85,60	68,10	29,50	0,00	0,00
Cooling	0,00	0,00	0,00	0,00	0,10	17,20
Domestic Hot Water	2,70	2,40	2,50	2,10	1,90	1,60
Total	156,20	88,00	70,60	31,60	2,00	18,80

Operational cost [€]	
	14885,00

Building E - A nursery and offices building

General characteristics

Google-earth. The building's orientation is SE.

Building General

Usage	**PUBLIC SERVICES BUILDING (LIBRARY, DISABLED SCHOOL)**		**Built before 1955. Re-stored. It is used for library (first floor) and disabled-school (ground floor).**		
Total floor area	176	m^2	Total volume	1.758,00	m^3
Heated floor area:	176	m^2	Heated volume	1.758,00	m^3
Cooled floor area	88	m^2	Cooled volume	879,00	m^3
Number of floors	2	m	Typical floor height	3	m
Number of thermal zones	1				
Number of unconditioned spaces	0				

Basement hei

RESULTS

Primary energy consumption [kWh/m^2]	Reference building	Building
Heating	114,80	605,10
Cooling	0,40	0,40
Domestic Hot Water	0,00	0,00
Lighting	123,50	102,80
Renewable Energy Sources	0,00	0,00
Total	238,70	708,40
Ranking (Energy Class)		H

Energy source	Fuel Consumption [kWh/m^2]	CO_2 Emissions [kg/m^2]
Electricity	185,40	183,40
Oil	0,00	0,00
Natural gas	549,70	107,70
Other fossil fuels	0,00	0,00
Solar	0,00	0,00
Biomass	0,00	0,00
Geothermal	0,00	0,00
Other RES	0,00	0,00
Total	599,00	291,10

Final energy consumption [kWh/m²]	Jan	Feb	Mar	Apr	May	Jun	July
Heating	131,00	103,10	81,80	35,30	0,00	0,00	0,(
Cooling	0,00	0,00	0,00	0,00	0,10	0,00	0,(
Domestic Hot Water	4,40	4,40	4,40	4,40	4,40	0,00	0,(
Total	135,40	107,50	86,20	39,70	4,50	0,00	0,(

Operational cost [€]	
	10716,00

		CLASS	SOURSE/PRIMARY [kWh/m²]	SITE [kWh/m²]	CO^2 EMISSIONS [kg/m²]	OPERATIONAL COST €
A	**MUNICIPALITY OFFICES BUILDING**	D	475,90	0	124,60	17.641,50
B	**CULTURAL ORGANIZA-TION BUILDING**	H	1.024,20	0	253,40	7.867,60
C	**1st PRIMARY SCHOOL BUILDING**	H	684,50	0	186,40	15.229,70
D	**LIBRARY AND DISABLED-SCHOOL BUILDING**	Z	1.006	0	264,40	14.885
E	**NURSERY AND OFFICES BUILDING**	H	708,40	0	291,10	10.716

THE TABLE SHOWS THAT BUILDING A HAS A HIGHER RANKING AND HAS THE LESS SOURCE ENERGY CONSUMPTION, LESS EMISSIONS AND LESS OPERATIONAL COST.

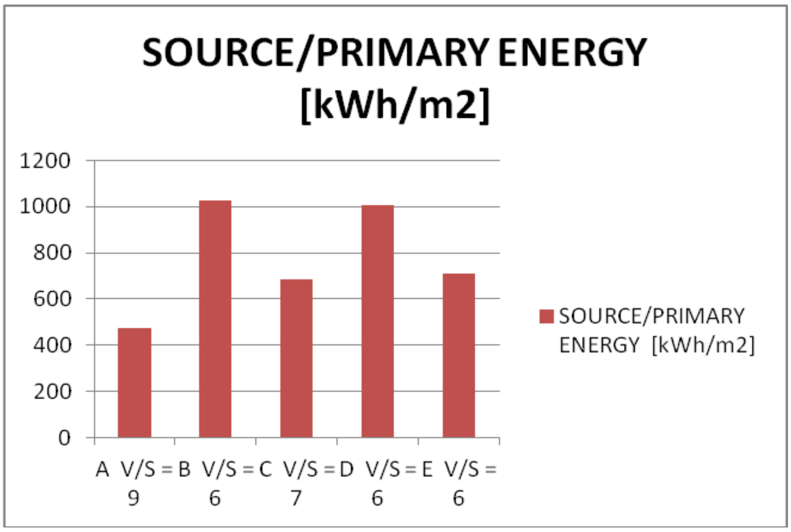
		FLOOR SURFACE S m²	VOLUME V m³	EXTERNAL SURFACE F m²	COM-PACTNESS V / S	USABLE AREA E m²	F / E %
A	**MUNICIPALITY OF-FICES BUILDING ***	616,68	5.550,16	1.282	**9**	1233,36	**1**
B	**CULTURAL ORGANI-ZATION BUILDING ***	130,00	780	532	**6**	260	**2**
C	**1st PRIMARY SCHOOL BUILDING ****	302,10	2.114,70	1.099	**7**	604,20	**1,8**
D	**LIBRARY AND DISABLED-SCHOOL BUILDING ****	260,00	1.560	766	**6**	520	**1,5**
E	**NURSERY AND OF-FICES BUILDING ****	176,00	1.056	661	**6**	352	**1,9**

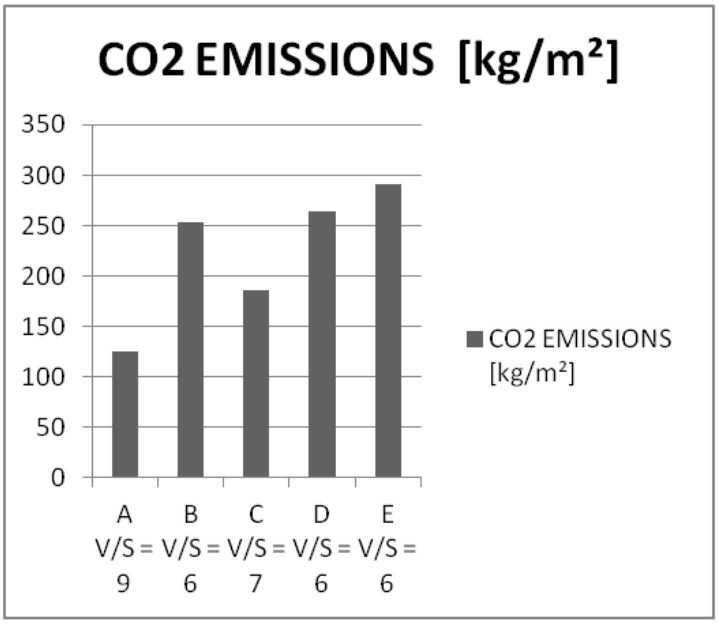
***RESTORED USING REINFORCED CONCREETE**
****RESTORED WITH NO CHANGES ON THE INITIAL STRUCTURE**

		FLOOR SURFACE S m2	VOLUME V m3	COMPACT-NESS V / S	ENCLOSURE SURFACE E m2	USABLE FLOOR F m2	F / E
A	**MUNICIPALITY OFFICES BUILD-ING**	616,68	5.550,16	**9**	1.282	1.233,36	**0,96**
B	**CULTURAL OR-GANIZATION**	130,00	780	**6**	532	260	**0,48**
C	**1st PRIMARY SCHOOL**	302,10	2.114,70	**7**	1.099	604,20	**0,54**
D	**LIBRARY AND DISABLED-SCHOOL**	260,00	1.560	**6**	766	520	**0,67**
E	**NURSERY AND OFFICES BUILD-ING**	176,00	1.056	**6**	661	352	**0,53**

The table shows that building A has also a higher compactness v/s and a higher f/e rate.

The German energy code prescribes lower energy consumption for buildings that are more compact (higher V/S value). The ratio F/E is a metric most preferable for office-commercial buildings, because it rewards buildings that require less floor-to-floor height, removing volume from the assessment.
The more compact the form, the higher the ratio F/E.





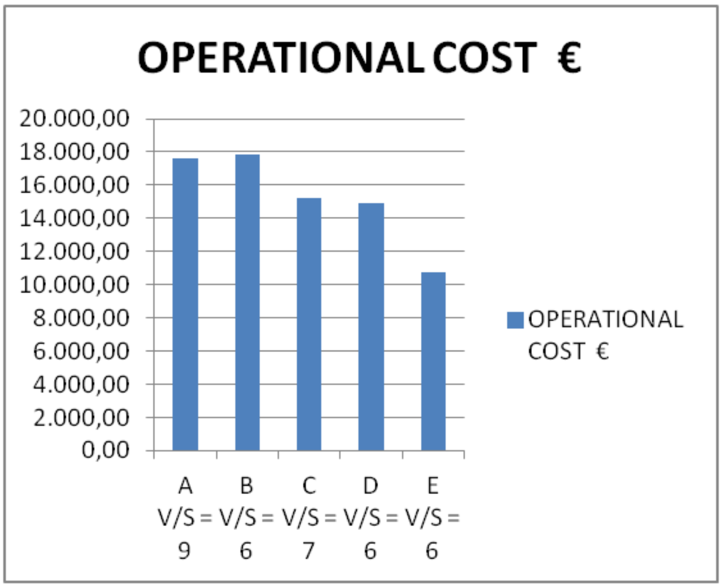
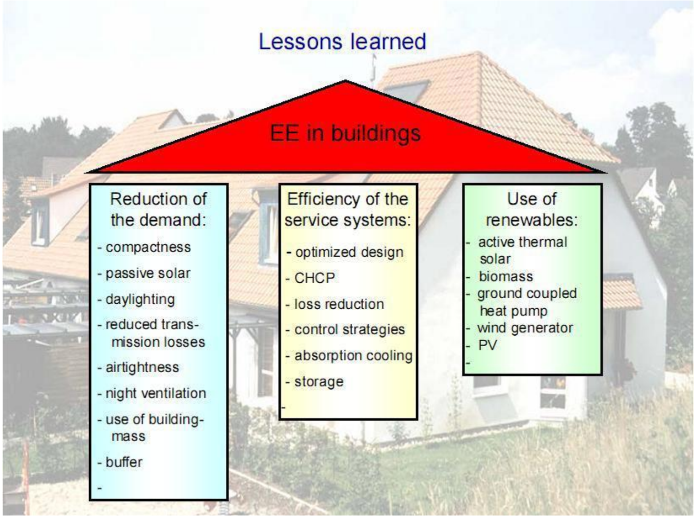


diagram 1 shows the primary energy consumption. Building A presents the less.
diagram 2 shows the operational cost. All buildings present high annual costs.
diagram 3 shows the CO2 emissions. Building A presents the less.

Table outlines the EEMs for office and school buildings.

Office buildings	**School buildings**
EEM	**EEM**
Lighting/Daylighting	**Lighting/Daylighting**
Building Lighting Power Density 0.8 watt/sf	
Night Sweep/Occupancy Sensors NC,	Night Sweep/Occupancy Sensors
Building Lighting Power Density 0.85 watt/sf	Building Lighting Power Density 0.85 watt/sf
Office Lighting Power Density 0.8 watt/sf	Office Lighting Power Density 1.4 watt/sf
Daylight Dimming Controls	Daylight Dimming Controls in Class-rooms
HVAC	**HVAC**
Demand Control Ventilation (DCV)	Variable Frequency Drive (VFD) HVAC Motors
Variable Frequency Drive (VFD) HVAC Motors	HVAC Chiller Efficiency 4.5 to 6.4 COP
Chilled Beams	Demand Control Ventilation (DCV) in Classrooms and Assembly Spaces
Boiler 90%+ Minimum Efficiency	Chilled Beams in Classrooms
Economizer Control	Boiler 90%+ Minimum Efficiency
Heat Recovery of Exhaust Flow	Infiltration 0.7 air change/hour
	Energy Recovery Ventilator (ERV) Variable Flow Kitchen Exhaust/MUA System
Envelope	**Envelope**
R-20 Roof Insulation	R-20 Roof Insulation
R-13 Wall Insulation	R-13 Wall Insulation
R-19 Wall Insulation	
Infiltration Reduction - Caulking	
Infiltration 0.20 air change/hour	Infiltration 0.35 air change/hour
Glazing	**Glazing**
U-0.32 or better	U-0.32 or better
Low-e Coated	Low-e Coated
Water Heating	**Water Heating**
Gas heat with 90% efficiency	Gas heat with 93% efficiency
Gas heat with 93% efficiency	Solar Thermal Hot Water
Solar Thermal Hot Water	Hot Water Pipe Insulation
Hot Water Pipe Insulation	



Managing the building stock - Energy renovation measures

Energy (thermal) loads in buildings can be dealt with in three (plus one) ways:
a) Avoiding or reducing in the first place their generation by applying the basic principles of energy design of buildings
b) Postponing their impact on the buildings' interior
c) Using renewable sources
d) Improving conventional HVAC

Renovation of the building's shell.
- Thermal and insulation of vertical and horizontal opaque building elements.
- Replacement of windows.
- Passive solar systems.
- Sun-protection.

Modernisation of the HVAC-DHW systems.
- Implementation of controls.
- Utilisation of new technologies in boilers and burners.
- Combination of renewable energy and conventional systems.
- Application of CHP and district heating schemes

But there are hurdles and problems:

The unsuitability of the densely built urban environment (An existing problem)

Lack of legislative obligations and incentives, complex legislative framework

Lack of financial incentive (The two most frequently mentioned barriers)

Lack of proven expertise and qualified professionals

Unwillingness to abandon the 'business as usual' approach (The two less easily acknowledged reasons)

Low energy prices (with respect to energy taxation)

Lack of energy and environmental consciousness (The truly political problems)

* All points mentioned are results of an EU wide FORESIGHT study (2004)

5. CONCLUSIONS

After the analysis and discussion made in the previous chapter, chapter 5 presents the conclusions drawn.

1. According to the definitions, a cost ZEB is the most difficult to achieve, though emissions ZEB is more easy to reach and reflects the climate relevance of a building's operation. Source ZEB is a better model for impact on national energy system and site ZEB encourages energy-efficient building designs.

2. According to shape and construction, <u>old buildings of a specific architectural type</u> are possible to achieve a higher energy performance. So we can say that they are Zero-Capable Buildings.

3. Old buildings include the advantage of having no construction costs, but only the retrofit cost. Upgrades result in lower energy consumption over the lifetime of a building and therefore yield a significant reduction in environmental impacts.

4. When comparing buildings of equivalent size and function, building reuse almost always offers environmental savings over demolition and new construction.

5. There are <u>limitations</u> to advance those buildings to ZEB, which has to do with the existing legislation for the protection of the architectural heritage.

6. Using appropriate EEMs during reuse, these buildings could be advanced to the category of nearly Zero Energy Building.

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APPENDIXES

APPENDIX I

Definitions *(Source: Deru and Torcellini 2007)*

Emission Factor

The mass of a pollutant emitted to the environment per unit of energy or fuel associated with the production, distribution, and use of the energy or fuel.

Precombustion Effects

The source energy used for and the emissions resulting from extracting, processing, and delivering a fuel to the point of use in a power plant or a building.

Primary Energy

The sum of the energy consumed at a facility and the energy required extracting, converting, and transmitting that energy to the facility. (Same as *source energy*)

Site Energy

The energy directly consumed at a facility typically measured with utility meters.

Source Energy

The sum of the energy consumed at a facility and the energy required extracting, converting, and transmitting that energy to the facility. The source energy for electricity from hydroelectric power, solar energy, and wind is assumed to be equal to the electricity produced at the source; however, the transmission and distribution losses are accounted for in the electricity delivered to the facility. Source energy for electricity from thermal electric power plants fueled by geothermal and biomass is determined by assuming an efficiency of 33% for electricity production.

Source Energy Factor

The unit of *source energy* consumed per unit of energy or fuel delivered to the facility.

Useful Thermal Output

The thermal energy made available for use in any industrial or commercial process, or used in any heating or cooling application; i.e., total thermal energy made available for processes and applications other than electrical generation (EIA 2005b).

APPENDIX II

***Conversions for Calculating Source Energy Use** (Source: Ueno and Straube, 2010)*

The following conversions from billed units to source energy are provided for some common fuel types. The energy use for the year should be added up, and then converted to million Btu/year (source) by type of fuel.

- Natural Gas: therms[1] × 0.1092 = million Btu (source energy)
- Electricity: kWh × 0.01148 = million Btu (source energy)
- Fuel Oil: gallons × 0.1781 = million Btu (source energy)
- Propane: gallons × 0.1187 = million Btu (source energy)

1: Note that natural gas use is often given in hundreds of cubic feet (CCF): this is roughly equivalent to therms, but requires a "thermal conversion factor" (typically 2-5%) to obtain therms.

As mentioned above, these conversions use today's site-source conversion factors, and assume certain fuel energy contents (Deru and Torcellini 2007), which will vary by region and time of year.

APPENDIX III

Calculation of U-values *(Source: Original)*

1. U-value of walls

- To external air
- To unconditioned spaces
- To adjacent spaces

2. U-value of roof

3. U-value of ground floor

- To basement
- To ground

4. U-value of intermediate floor

5. U-value of windows

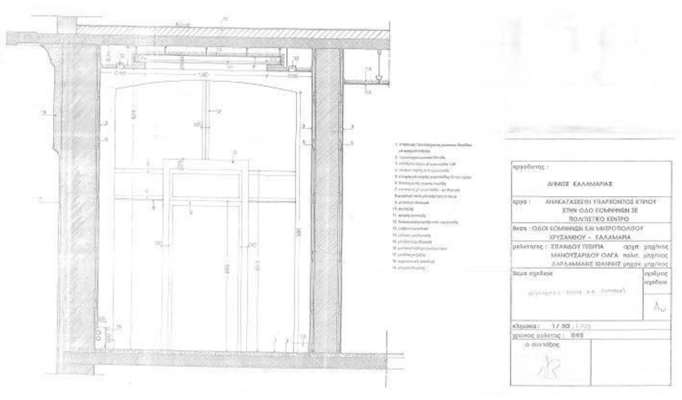
6. U-value of doors

- External front
- External back

Calculation of U-values *(Source: Original)*

Building A

WALLS (opaque elements)



TOTAL 1200

.

1^{st} FLOOR	**608,30**	-95 m2
GROUND FLOOR	**579,05 m2**	-107 m2
Staircase on roof	**32,5**	-4 m2

Wall ground floor d = 0,55m

Wall 1^{st} floor d = 0,45m

Rwall = Rext + R1 + R2 + R3 + R4 + R5 + R6 + Rint W/m^2k

Rext = External surface resistance 0,04

R1= exterior cement plaster = d / λ = 0,02 / 0,8 = 0,16

R2= reinforced concrete = d / λ = 0,05 / 2,5 = 0,125

R3= solid brick historical = d / λ = 0,30 / 0,6 = 0,18 (**1st floor)**

0,40 / 0,6 = 0,24 (**ground floor)**

R4= air gap = d / λ = 0,05 / …. =

R5= gypsum board = d / λ = 0,01 / 0,25 = 0,0025

R6= interior plaster = d / λ = 0,02 / 0,2 = 0,004

Rint = Internal surface resistance 0,13

R(wall ground floor) = 0,04 + 0, + 0,022 + 0,02 + … + 0,04 + 0,017 + 0,13 = W/m^{2}k

R(wall 1st floor) = 0,04 + 0, + 0,022 + 0,02 + … + 0,04 + 0,017 + 0,13 = W/m^{2}k

U-value (wall ground floor) = 1/R(wall ground floor) =

U-value (wall 1st floor) = 1/R(wall 1st floor) =

Rroof = Rext + R1 + R2 + R3 + R4 + R5 + Rint W/m^{2}k

Rext External surface resistance 0,04

R1= exterior roof membrane = d / λ = 0,02 / 0,16 = 0,32

R2= reinforced concrete = d / λ = 0,15 / 2,5 = 0,375

R3= air gap = d / λ = 0,05 / …. =

R4= gypsum board = d / λ = 0,01 / 0,25 = 0,0025

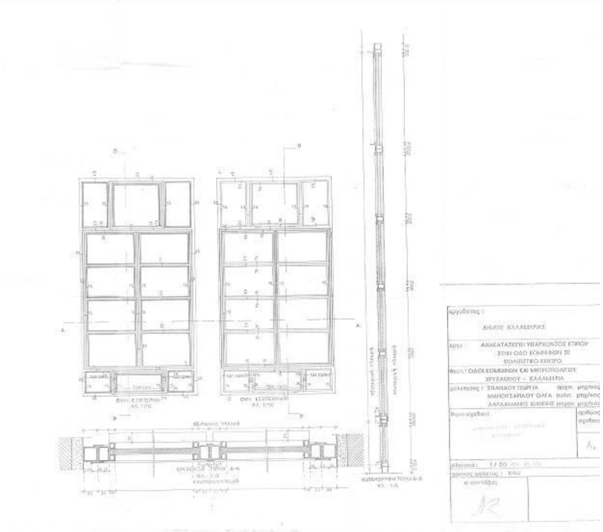
R5= interior plaster = d / λ = 0,02 / 0,2 = 0,004

Rint Internal surface resistance 0,13

R(roof) = 0,04 + 0,32 + 0,375 + … + 0,0025 + 0,004+ 0,13 = W/m^{2}k

U-value (roof) = 1/R(roof) =

WINDOWS (transparent elements)



TOTAL OPENINGS 206 m2

1^{st} FLOOR	95 m2
GROUND FLOOR	107 m2
Staircase on roof	4 m2

CALCULATIONS

Aluminum frame without thermal break,

40% frame, double glazed U = 6,2 W/(m2K)

Uf = 2,00

Ug = 1,50

1st floor north-west 29.30 m2

(1.25 * 2.58) = 3.225 m2 * 8 windows = 25,80 m2

[1.380m2 frame / 1.845m2 glass / l= 22 m]

U-value = (Af *Uf + Ag*Ug + lg*Ug) / Af+Ag = 1.380m2*2,00 + 1.845m2*1,50 + 22*1,50 / 3.225 m2 = 2,76 + 2,76 + 33 / = 38,52 / 3,22 = **11,96**

(1.36 * 2.58) = 3.508 m2 * 1 window

[1.190 m2 frame / 2.317m2 glass / l= 23 m]

U-value = (Af *Uf + Ag*Ug + lg*Ug) / Af+Ag = 1.190 m2 *2,00 + 2.317m2 *1,50 + 23*1,50 / 3.508 m2 =

1st floor south-east 28.65 m2

(1.25 * 2.58) = 3.225 m2 * 7 windows = 22,57 m2

[1.380 m2 frame / 1.845 m2 glass / l= 22 m]

1 (glazed door to balcony) * (1.62 * 3.75) = 6.075 m2

[1.580 m2 frame / 4.495 m2 glass / l = 29,50 m]

1st floor north-east 14.57 m2

(1.25 * 2.58) = 3.225 m2 * 1 window

[1.144 m2 frame / 2.080 m2 glass / l= 22 m]

(on north-west façade looking east)

(1.25 * 2.58) = 3.225 m2 * 2 windows = 6,45 m2

[1.144 m2 frame / 2.080 m2 glass / l = 22 m]

(north facade)

(0.90 * 2.73) = 2.457 m2 * 2 windows = 4,91 m2

[1.033 m2 frame / 1.423 m2 glass / l= 20 m]

1st floor west 21.00 m2

(1.25 * 2.58) = 3.225 m2 * 3 windows = 9,67 m2

[1.144 m2 frame / 2,080 m2 glass / l= 22 m]

(on north facade looking west)

(1.25 * 2.58) = 3.225 m2 * 2 windows = 6,45 m2

[1.144 m2 frame / 2,080 m2 glass / l= 22 m]

(north facade)

(0.90 * 2.73) = 2.457 m2 * 2 windows = 4,91 m2

[1.033 m2 frame / 1.423 m2 glass / l= 20 m]

Ground floor north 25,80 m2

(1.25 * 2.58) = 3.225 m2 * 8 windows = 25,80 m2

[1.144 m2 frame / 2,080 m2 glass / l= …..m]

Ground floor south 22,57 m2

(1.25 * 2.58) = 3.225 m2 * 7 windows = 22,57 m2

[1.144 m2 frame / 2.080 m2 glass / l= 22 m]

Ground floor east 14.58 m2

(1.25 * 2.58) = 3.225 m2 * 1 window

[1.144 m2 frame / 2.080 m2 glass / l= 22 m]

(north facade)

(1.25 * 2.58) = 3.225 m2 * 2 windows = 6,45 m2

[1.144 m2 frame / 2.080 m2 glass / l= 22 m]

(north facade)

(0.90 * 2.73) = 2.457 m2 * 2 windows = 4,91 m2

[1.033 m2 frame / 1.423 m2 glass / l= 20 m]

Ground floor west 24.26 m2

(1.25 * 2.58) = 3.225 m2 * 4 windows = 12,90 m2

[1.144 m2 frame / 2,080 m2 glass / l= 22 m]

(north facade)

(1.25 * 2.58) = 3.225 m2 * 2 windows = 6,45 m2

[1.144 m2 frame / 2.080 m2 glass / l= 22 m]

(north facade)

(0.90 * 2.73) = 2.457 m2 * 2 windows = 4,914 m2

[1.033 m2 frame / 1.423 m2 glass / l= 20 m]

DOORS   20,38 m2

Ground floor south

1 door (**main entrance wooden door**) (1.62 * 3.75) = 6.075 m2

External door south <u>U-value 3,5 W/m2K</u>

Start 0,00 m End +3,75 m Width 1,62 m

Ground floor north (wooden doors)

2 doors * (1.30 * 3.73) = 4.849m2 *2= 9,70 m2

External doors north <u>U-value 3,5 W/m2K</u>

Start 0,00   End +3,73 Width 1,30

1st floor west 1 door (**emergency exit**) (1.30 * 3.73) = 4.849m2 (aluminum door) <u>U-value 6,0 W/m2K</u>

Staircase on roof north 2 doors * (1.00 * 2,00) = 2,00 m2 *2 = 4,00 m2

(aluminum doors) <u>U-value 6,0 W/m2K</u>

GROUND FLOOR 616,68 m2 total

To basement (as adjacent space) **40 m2**

No calculation needed, no internal door

To ground **576,68 m2** <u>U-value 0,28 W/m2K</u>

U nominal = 0,6

B = (2*A)/P = 8,3577

U = (from table) = 0,28

INTERMEDIATE FLOOR

616,68 m2

No calculation needed, same thermal zone

ROOF (flat roof – no insulation)

616,68 m2

<u>U-value 3,05 W/m2K</u>

<u>External shading factors</u>

SHADING FROM OVERHANGS   Fo

Balcony 1st floor, orientation SE

L1=1.20m overhang

WALL

H2= 4,50/2=2,25m

T ancle b = L1/H2 = 1,20/2,25 = 0,53 …… ????

F heating period =

F cooling period =

F total = Fh + Fc =

Wooden door main entrance

H2= 3,70/2=1,85m

T ancle b = L1/H2 = 1,20/1,85 = 0,65   …… ????

F heating period =

F cooling period =

Fo total = Fh + Fc =

SHADING FROM THE HORIZON   Fh

Opposite building = the same building

10,00m height

d=6,50m

WALLS Ground floor

H2= 4,50/2=2,25m

B1C=10-2,25= 7,75m

T ancle b = B1C/d = 7,75/6,50 = …… ????

F heating period =

F cooling period =

Fo total = Fh + Fc =

WALLS <u>1st floor</u>

H2= 4,50/2=2,25m

B2C=10-6,55= 3,45m

T ancle b = B2C/d = 3,45/6,50 = …… ????

F heating period =

F cooling period =

Fo total = Fh + Fc =

WINDOWS (90) Ground floor

H2= 2,50m

B1C=10-2,50= 7,50m

T ancle b = B1C/d = 7,50/6,50 = …… ????

F heating period =

F cooling period =

Fo total = Fh + Fc =

WINDOWS (90) 1st floor

H2= 7,00m

B2C=10-7= 3,00m

T ancle b = B2C/d = 3,00/6,50 = …… ????

F heating period =

F cooling period =

Fo total = Fh + Fc =

WINDOWS (1,20) Ground floor

H2= 2,50m

B1C=10-2,50= 7,50m

T ancle b = B1C/d = 7,50/6,50 = …… ????

F heating period =

F cooling period =

Fo total = Fh + Fc =

WINDOWS (1,20) 1st floor

H2= 7,00m

B2C=10-7= 3,00m

T ancle b = B2C/d = 3,00/6,50 = …… ????

F heating period =

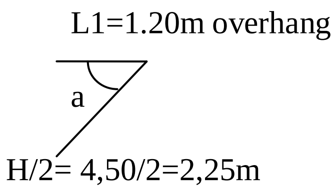
F cooling period =

Fo total = Fh + Fc =

External shading factors

SHADING FROM OVERHANGS Fo

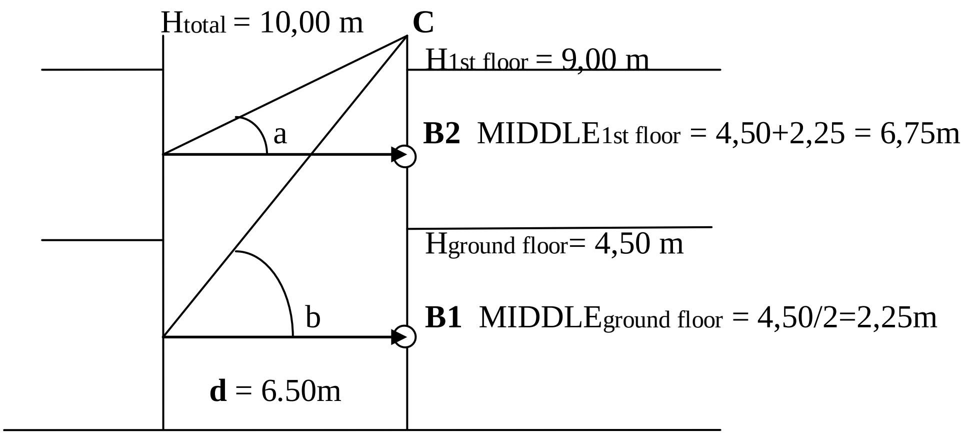
Balcony 1st floor, orientation SE



WALL
H2= 4,50/2=2,25m
T ancle b = L1/H2 = 1,20/2,25 = 0,53
F heating period =
F cooling period =
F total = Fh + Fc =

Wooden door main entrance
H2= 3,70/2=1,85m
T ancle b = L1/H2 = 1,20/1,85 = 0,65
F heating period =
F cooling period =
Fo total = Fh + Fc =

SHADING FROM THE HORIZON Fh



Opposite building = the same building

d=6,50 m
H_{total} = 10,00 m
$H_{1st\ floor}$ = 9,00 m
$H_{ground\ floor}$= 4,50 m

WALLS <u>Ground floor</u>

B1 MIDDLE$_{\text{ground floor}}$ = 4,50/2=2,25m
B1C=10,00 - 2,25= 7,75m
T ancle b = B1C/d = 7,75/6,50 = 1,19
F heating period =
F cooling period =
Fo total = Fh + Fc =

WALLS <u>1st floor</u>

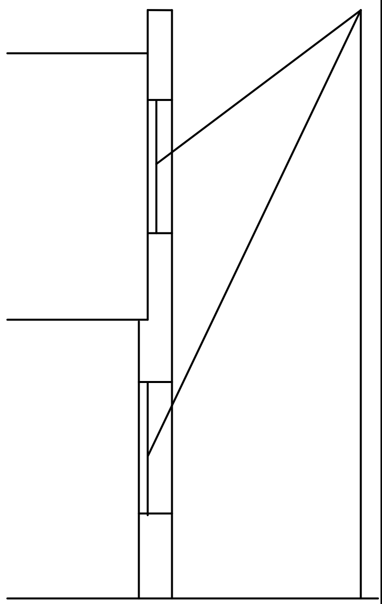
B2 MIDDLE$_{\text{1st floor}}$ = 4,50+2,25 = 6,75m
B2C=10,00 - 6,75= 3,25m
T ancle b = B2C/d = 3,25/6,50 = 0,5
F heating period =
F cooling period =
Fo total = Fh + Fc =

WINDOWS (0,90) <u>Ground floor</u>
(window 1,10 / 3,73)

B1 MIDDLE$_{\text{ground floor}}$ = 2,50m
B1C=10,00 - 2,50= 7,50m
d = 6,50 + 0,50 = 7,00m
T ancle b = B1C/d = 7,50/7,00 =
F heating period =
F cooling period =
Fo total = Fh + Fc =

WINDOWS (0,90) <u>1st floor</u>
(window 1,10 / 3,73)

B2 MIDDLE$_{\text{1st floor}}$ = 7,00m
B2C=10,00 – 7,00= 3,00m
d = 6,50 + 0,40 = 6,90m
T ancle b = B2C/d = 3,00/6,90 =
F heating period =
F cooling period =
Fo total = Fh + Fc =

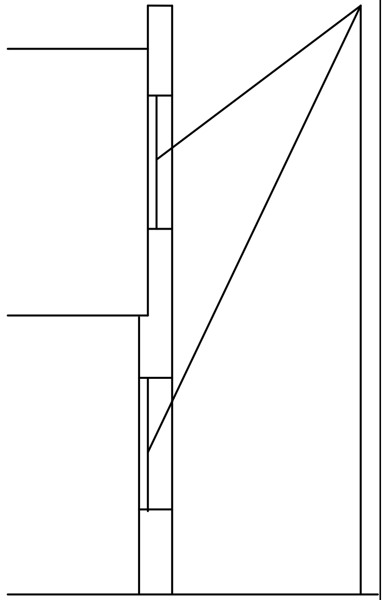


WINDOWS (1,20) Ground floor
(window 1,25 / 3,75)

B1 MIDDLE$_{\text{ground floor}}$ = 2,50m
B1C=10,00 - 2,50= 7,50m
d = 6,50 + 0,50 = 7,00m
T ancle b = B1C/d = 7,50/7,00 =
F heating period =
F cooling period =
Fo total = Fh + Fc =

WINDOWS (1,20) 1st floor
(window 1,25 / 3,75)

B2 MIDDLE$_{\text{1st floor}}$ = 7,00m
B2C=10,00 – 7,00= 3,00m
d = 6,50 + 0,40 = 6,90m
T ancle b = B2C/d = 3,00/6,90 =
F heating period =
F cooling period =
Fo total = Fh + Fc =



SHADING FROM VERTICAL ELEMENTS – FINS Ff

Calculation of the total system energy consumption for heating

Heating system

Natural gas fired boiler

Power 315.000 kcal/h * 0,001162 = **366 kW**

Efficiency 91 + 1*log(Pn) =

ngen = ngm + ng1 + ng2 =

ngen = overall efficiency

ngm = nominal efficiency = 88,6 (from the maintenance sheet)

ng1 = if oversized

ng2 = according to insulation level of the boiler = 0.951 (from table)

P heating = A * Um * ΔT * 2,5

A = Total external surface of the building (+surfaces attached) =

Um = mean thermal transmittance factor

ΔT = 23oC for climatic zone C

COP = 1.7 (17 years old)

Distribution system

Pipes routing through internal spaces – no insulation

Output temperature = 65oC

Supply temp. > 60 (from table) = **9.2**

Emission system

60 Fan coils Efficiency = 0.93

Ceiling system Efficiency = 0.90

e) Implementation of Energy Saving Measures in order to improve the overall energy efficiency of the building

ENERGY SAVING MEASURES
Apply to:

1. **Building envelope**

1.1 Shadings
No intervention is permitted on the building's façade.

1.2 Roof insulation
Additional insulation of 0,05m
Rins = d/ λ = 0,05 / 0,039 = 1,28

R(roof) = 0,04 + 0,32 + 0,375 + 0,5 + 0,0025 + 0,004 + 0,13 = **1,37**

R(roof) = **1,37 +** 1,28 = **2,65**

U-value (roof) = 1/R(roof) = 1 / 2,65 = 0,37 W/m2k
(before 0,73)

1.3 External wall insulation
If the air gap between the gypsum board and the brick wall is filled by insulation, then the Rwall would be:

Rwall = Rext + R1 + R2 + R3 + R4 + R5 + R6 + Rint

Rext External surface resistance 0,04
R1= exterior cement plaster = d / λ = 0,02 / 0,8 = 0,0025
R2= reinforced concrete = d / λ = 0,05 / 2,5 = 0,02
R3= solid brick historical = d / λ = 0,30 / 0,6 = 0,5 (**1st floor)**
0,40 / 0,6 = 0,66 (**ground floor)**
R4= air gap - insulation = d / λ = 0,05 / 0,039 = 1,28
R5= gypsum board = d / λ = 0,01 / 0,25 = 0,04
R6= interior plaster = d / λ = 0,02 / 0,2 = 0,1
Rint Internal surface resistance 0,13

R(wall ground floor) = 0,04 + 0,0025 + 0,02 + 0,66 + 1,28 + 0,04 + 0,1 + 0,13 = 2,27

R(wall 1st floor) = 0,04 + 0,0025 + 0,02 + 0,5 + 1,28 + 0,04 + 0,1 + 0,13 = 2,11

U-value (wall ground floor) = 1/R(wall ground floor) = 1/ 2,27 = <u>0,44</u> W/m2k (before 0,60)

U-value (wall 1st floor) = 1/R(wall 1st floor) = 1/ 2,11 = <u>0,47</u> W/m2k (before 0,66)

2. <u>Electromechanical installations</u>
Boiler maintenance or new boiler
Heat recovery ventilation system
Cogeneration
Install BEMS

3. <u>Renewable energy sources</u>
Photovoltaics on the roof
Photovoltaics on external canopy
Geothermal installation

Buildings for public services need to display the energy performance visible to the public.

Calculation of U-values *(Source: Original)*

Building B

Calculation of U-values *(Source: Original)*

Building C

Calculation of U-values *(Source: Original)*

Building D

Calculation of U-values *(Source: Original)*

Building E

APPENDIX IV

***Input data** (Source: Original)*

Set points for temperature and RH for offices are:

Hp	Cp	Hp	Cp
20	26	35%	45%

External mean temperatures per month for Thessaloniki - Climatic zone C

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5,3	6,8	9,8	14,3	19,7	24,5	26,8	26,2	21,9	16,3	11,1	6,9

Define the total operational hours for office buildings

10hours/day 5days/week 12months/year

Define the total operational hours for school buildings

6 hours/day 5 days/week 9 months/year

Heat transfer by ventilation.

Infiltration for aluminum or PVC frame for double glazing, opening system

4,8 for doors / 6,2 for windows

Natural ventilation for offices

10 occupants/m^2 30m^3/h/person 3m^3/h/m^2 air flow

Internal heat sources

From occupants - lighting - appliances

Other not taken under consideration / account

For offices:

- occupants flow rate 80 W/occupant / 8 W/m2 / 0,3 mean presence factor
- lighting illuminance lux 500 / level above floor 0,8 m
- appliances 15 W/m2 nominal rate / 0,3 mean operation factor / 4,5 flow rate

<u>Solar heat sources</u>

Glazing

External opaque elements

Internal walls and floors of sunspaces

Walls behind transparent covering

Typical value of **g factor** (solar energy transmittance) for double glazing is 0,75

<u>Calculation of the dynamic parameters</u>

The gain utilization factor for heating nH

The loss utilization factor for cooling nC

The gain / loss ratio **γ**H

The building inertia aH Dimensionless numerical parameter **a**

For offices a = 0,8

A reference time constant of the building **τ**

For offices τ = 70